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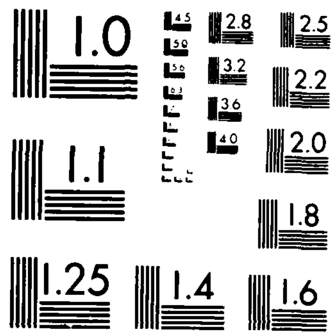

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STATION LOADING ON THE DATSA (DEPOT AUTOMATED TEST STATION FOR AVIONICS)

THESIS

Larry D. Bottomley
Captain, USAF

AFIT/GLM/LSY/86S-7

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STATION LOADING ON THE DATSA
(DEPOT AUTOMATED TEST STATION FOR AVIONICS)

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

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In Partial Fulfillment of the

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Master of Science in Logistics Management

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Captain, USAF

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Preface

This research project only examines the depot level maintenance at one of four depots using the DATSA (Depot Automated Test Station for Avionics) for the B1-B. The model, developed to simulate the repair process, can be used for any depot merely by changing the appropriate variables after the computer program is started. The variables are easily changed because of a new simulation environment called SIMPLE 1. The simulation language, developed by Mr. Philip Cobbin, provided the needed flexibility to accomplish this type of model.

I would like to thank Mr. Cobbin for his help with the language and Lt. Col. Richard Peschke for introducing me to SIMPLE 1. I would also like to thank my thesis advisor, Maj. Hitzelberger, for his patience, trust, and editorial assistance during this research project. Finally, I need to express my thanks to my family for their moral support this past year.

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Abstract

This research investigates the repair process for B1-B avionic Shop Replaceable Units (SRUs) at the depot level of maintenance. A Depot Automated Test Station for Avionics (DATSA) is used to test these SRUs for faults. A computer model provides the environment for the simulation and comparison of different amounts of DATSAs at the depot at Robbins AFB, Georgia.

SIMPLE 1 is the simulation language used by the model. It was chosen primarily because it can be used on any IBM or IBM compatible personal computer, and it does not require a simulation expert to run. The model's user-friendly input screens allow for changes to be made for future simulations as more data becomes available on the SRU repair process.

The simulations used a SRU arrival rate based on an aggregate Mean Time Between Demand for the SRUs. Simulations were conducted using various quantities of DATSAS. The differences between key variables in the different systems were compared and confidence intervals were computed. Synchronized random number streams were used as a variance reduction technique to determine compact confidence intervals. Sensitivity analysis was also accomplished by

varying the quantities of workers available and the average daily flying time of the B1-B.

The results indicated a minimum of eight test stations would be able to accomodate the anticipated SRU load at the depot. However, the time the average SRU was delayed in the depot also increased as the number of DATSAs was decreased. With only eight DATSAs in operation, the cost of the added delay might exceed the cost of another DATSA. Also, as the flying time was increased, an infinite queue of faulty SRUs began to accumulate with only eight DATSAs in operation. Nine DATSAs were easily able to accomodate a 10 percent increase in average daily flying time.

STATION LOADING ON THE DATSA
(DEPOT AUTOMATED TEST STATION FOR AVIONICS)

I. The Introduction

General Issue

The B1-B strategic bomber is a highly complex weapon system. It utilizes a modular component design to expedite and simplify maintenance. An avionics system failure on the aircraft is traced to a Line Replaceable Unit (LRU), or "black box." The LRU is removed from the aircraft and replaced with another LRU. The malfunctioning LRU is sent to the base avionics maintenance shop for repair. In the shop the LRU is checked with Automatic Test Equipment (ATE), and the faulty circuit board within the black box or Shop Replaceable Unit (SRU) is removed and replaced. The faulty SRU is sent to a depot for repair. At the depot the SRU is tested with the Depot Automated Test Station for Avionics (DATSA), and then it is repaired and returned to service. The quantity of test stations at the depot must be enough to insure a reasonable repair time at the depot, or the inventory of spare SRUs will be depleted before it can be replenished. The resulting shortage of spare SRUs could seriously affect our strategic bomber capability by grounding combat aircraft. However, an excessive number of

stations would add millions of dollars to the program's total cost.

Problem Statement

The B1-B System Program Office, SPO, has ordered 30 DATSAs from Emerson Corporation. The DATSAs are to be located at four different depots, and each depot will be responsible for different types of SRUs. Currently, a few of the DATSAs have been sent out to the depots. The remainder are scheduled for gradual implementation until June of 1988, when all stations should be in place as the last of the 100 new B1-B aircraft become operational (12).

The SPO is concerned that 30 test stations may not be enough to handle the depot maintenance of the SRUs. Rockwell International Corporation projected a need for 46 stations. But the Technology Repair Centers (TRCs), a part of Air Force Logistics Command (AFLC) and responsible for maintenance and repair at the depots, projected a need for 30 stations (12). The SPO not only needs to know if 30 test stations are enough, but how many to place at each of the four depots to insure a minimal repair time without committing an excessive number of DATSAs.

Research Objectives and Scope

Complicated models capable of doing this simulation already exist, but because of their expense or complex nature, they are relatively inaccessible to smaller planning groups. The objective of this research was to develop a

model to assist the B1-B SPO with their decision on the quantities of DATSAs to place at each depot.

The nature of this research was to analyze failed avionic SRUs as they travel through depot repair, not to model each individual SRU in the entire system (see System Definition in Chapter 2). The planned 100 B1-B aircraft contain more than 400,000 avionic SRUs alone, not counting any SRUs held in inventory. A model of this complexity would not be adaptable or flexible enough to allow the many changes that occur in an evolving weapon system.

The objective was to provide the B1-B SPO a user-friendly computer model for use in determining the proper quantities of test stations at each depot. The model was built to examine the depot defensive avionic SRU repair at Robbins AFB, and analyze how many DATSAs are needed there. But the model is generic and user-friendly enough to allow even non-experts the opportunity of using the model as input data changes or for analyzing other depots or test stations.

Literature Review

This research project builds on research conducted by Captain Lance M. Roark, a 1983 Air Force Institute of Technology (AFIT) graduate. His topic was the intermediate level of maintenance accomplished at the local base level. He designed a model to determine how many of the various types of Intermediate Automatic Test Equipment (IATE) would be required (14:3). At the time of its development, the

model provided very useful information to the B1-B SPO. However, most of his data (as well as most data used by this project) were estimates furnished by the contractors at Rockwell International. When more actual data began to be collected, he was not available to run simulations using new data on his model. Despite the fact he also included an operating manual for the model, it was too complex for the SPO personnel to use. They were unable to use it to adjust their estimates of IATE requirements. Thus this project will continue the analysis to depot level maintenance and carry along the lessons learned regarding simplicity.

To adequately understand and duplicate a system, a knowledge of the system boundaries is necessary. Mize and Cox provide excellent descriptions of many required terms. A simulation is

> ... the process of conducting experiments on a model of a system in lieu of either (1) direct experimentation with the system itself, or (2) direct analytical solution of some problem associated with the system. (11:1)

A system is "a set of objects united by some form of interaction or independence" (11:1). A model is a representation of all or part of the real system, and an experiment is the act of observing the performance of the model or system under various conditions.

The system in this model is depot level maintenance at Robbins AFB for B1-B avionic SRUs repairable on the DATSA. The experiments change the number of test stations available to examine the number required. Also, a sensitivity

analysis of the output was accomplished by varying the average daily flying time to observe the results if the input data were to change. This sensitivity analysis also substantiates the model's face validity. A model's face validity is its ability to appear "reasonable on its face to model users and others who are knowledgeable about the real system being simulated (2:385).

Fishman lists several of the technical attractions of simulation (7:4-5). Simulations can compress time, control sources of variation, eliminate errors of measurement, and allow an experiment to be replicated. Also, simulations can stop, record, and review all relevant states during an experiment without hindering the process of the system. Unfortunately, they also can become so complex trying to account for every minute detail that they fail to provide useful solutions.

The depot level SRU repair can be thought of as a queueing system, or a "collection of demands that arise as time evolves and that request service from one or several of a collection of resources" (7:13). The number of DATSAs required corresponds to the number of servers in a queue. Waiting time for repair decreases as the number of servers increases, but after a point the idle time of the servers increases to the point where it is no longer efficient.

> This illustrates the double-edged character of performance, and it is the balancing of these conflicting objectives that represents the essence of the study of a queueing system. (7:17)

DATSAs are expensive, but too few of them could leave the strategic forces in a decreased state of readiness.

The queue at the depot has the main attributes of any queueing system. The arrival rate of failed SRUs is given by their Mean Time Between Demand (MTBD). Their reliability is given by their Mean Time Between Failure (MTBF), but the depot is concerned with the actual demand rate on supply (12). The MTBD is a smaller number than the MTBF because it incorporates other types of failures besides those due solely to an inherent failure in the component itself. Other types of failures would include those due to neglect, maintenance malpractice, or components that retest okay.

Cooper provides excellent descriptions of the different types of arrival and service time distributions to use in various models. The poisson distribution is a favorite arrival distribution because of its memoryless property (5:45). Memoryless means the arrival of any entity (SRU) is completely independent of when the last arrival was. This same principle applies to using exponential service (repair) times (5:38). Uses of both distributions are well-discussed by Banks and Carson (2).

Banks and Carson also list the steps used to conduct a simulation. These will be covered in Chapter III of this thesis. Cobbin provides the inputs for the actual model building, also in Chapter III of this thesis. The methods of analysis described by all three authors will be used to assist in analyzing the results of the simulations.

II. The Background

Starting in mid-1985, the first B1-Bs began arriving at Dyess AFB, Texas. By the end of 1986, Dyess should have all of its scheduled 29 aircraft. The next 35 aircraft are planned to arrive at Ellsworth AFB, South Dakota, between November, 1986 and July, 1987. Grand Forks AFB, North Dakota should have its 17 aircraft by the end of 1987, and the last 17 go to McConnell AFB, Kansas by mid-1988 (10). To support aircraft depot maintenance, the DATSAs are also being implemented gradually to be fully operational by mid-1988 (12).

The B1-B utilizes three main levels of indenture for maintenance. The organizational and intermediate levels of maintenance occur at the local base level, and the depot level of maintenance occurs at a Technology Repair Center (TRC) usually co-located with an Air Logistics Center (ALC).

Organizational Maintenance

The organizational maintenance personnel (OMS) meet the aircraft after its mission to investigate any malfunctions reported by the flight crew at the maintenance debriefing. The bulk of the B1-B's avionics can be grouped into three categories -- offensive avionics, defensive avionics, and the Central Integrated Test System (CITS) (14:16). The CITS automatically accomplishes fault tests on the avionic equip-

ment during flight. This aids both the operations and maintenance crews in troubleshooting malfunctions. The malfunction can usually be isolated to one Line Replaceable Unit (LRU). A LRU is "any assembly which can be removed as a unit from the system at the operating location" (6:1-1). This malfunctioning LRU is removed and replaced with another LRU from base supply. The faulty LRU is then sent to a base level avionics repair facility (AMS) for test and repair.

Intermediate Maintenance

The B1-B's avionic systems have more than 424 LRUs of which 212 are repairable. One hundred and nine LRUs will be repaired at the base level on Automatic Test Equipment (ATE), 103 will be repaired at the depot level, and 212 will be discarded (14:16). A repairable LRU is connected to a computerized test station, and the station conducts a series of tests on the LRU to determine the malfunction. Usually the fault can be traced to a Shop Replaceable Unit (SRU).

A SRU is "a module for an LRU which can be removed from the LRU at an intermediate repair facility" (6:1-1). If a SRU is malfunctioning, it is removed and replaced with another SRU from supply. The repaired LRU returns to supply, and the bad SRU is sent to depot for repair. Base supply orders SRUs from the depot as its stock becomes depleted. Any LRU that is scheduled to be repaired at depot or that cannot be repaired is also sent to the depot for repair.

Base supply is responsible for maintaining the proper levels of stock in LRUs and SRUs. Some commonly used SRUs will be held as bench stock in the avionics shop, but the rest will be ordered from supply. Supply will order the LRUs and SRUs from the appropriate depot.

The test equipment used in the avionics shop is called IATE (Intermediate Automatic Test Equipment). LRUs are attached to the test station through a hardware interface. Electronic tests are performed through the use of computer software programs. The IATE also has many LRUs in its composition, so test station failures can be rapidly repaired. IATE LRUs can also be tested on the IATE and repaired at the base level by removing and replacing the faulty SRU. The test station SRUs are sent to depot at San Antonio ALC for testing and repair.

Depot Maintenance

Presently four depots have been named to test the avionics SRUs for the B1-B: Warner Robbins ALC, Oklahoma City ALC, San Antonio ALC, and Sacremento ALC. Each aircraft contains more than 1300 different types of SRUs, and they can be tested with a test station called DATSA, Depot Automated Test Station for Avionics (12). As mentioned before, San Antonio will handle all SRUs from IATE stations at each of the four bomber bases. Warner Robbins will be tasked with the ALQ-161 SRUs. The ALQ-161 is the defensive avionics package used for Electronic Warfare (EW).

It consists of 514 SRUs. Sacremento is getting one DATSA to use in its repair of SRUs from a specialized type of instrumentation. The rest of the SRUs will be repaired at Oklahoma City (12). Test Program Sets (TPSs), the computer software that drives the different SRU tests are currently being developed at the depots on the DATSA (12). Future weapon systems consisting of LRUs and SRUs can utilize this same DATSA by merely using different interfaces and TPSs.

The data used in this model is from the B1-B SPO. They obtained the individual MTBD for each type of SRU from the contractors. The contractors based the estimates on reliability rates from similar components used on different systems and on the data they are beginning to acquire from the field from the B1-Bs that are flying (10). The Mean Time To Repair (MTTR) is also estimated the same way. The projected B1-B flying time is from Headquarters SAC (Strategic Air Command).

AFSC/AFLC Re lation 800-23 sets the policy for the purchase and use of Modular Automated Test Equipment (MATE) to the maximum extent possible. It "requires all AFSC/AFLC organizations that acquire, modify, replace, and support AF systems that require ATE to follow this policy" (8). The DATSA, like the IATE, is composed of modular components that can be mixed and matched to a degree. The DATSA is composed of LRUs and SRUs which can be removed and replaced and sent to San Antonio ALC for testing and repair.

III. The Methodology

Banks and Carson present a useful list of steps to follow in a simulation study (2:11-15). These steps provide the framework for the discussion of the method used. The first two steps, problem formulation and setting of objectives, have already been accomplished. The report of results is contained in Chapter 4, and conclusions and recommendations are in Chapter 5.

Model Building

The discrete section of the model is made up of three main parts. The first part, the clock section, is the sequencer of daily activities. The second part, the failure section, is concerned with creating failed SRUs, assigning them a type and repair times, and shipping them to the depot. The last part, the repair section, models the repair process at the depot.

The Clock Section. The clock serves as the time keeper to sequence events properly in a normal work week. Each weekday it randomly assigns shipping times from the four B1-B bases, updates the display screen, and controls the work activity. Work starts at 0730 each weekday morning, and the lunch break is from 1130 to 1215. The workers repair SRUs for four more hours and leave work at 1615. Work starts again the next day at 0730. Work ending at 1615 on Friday waits until Monday morning to start again. The

clock provides preempts to interrupt work for lunch, evenings, and weekends. The shipping times, generated by the clock, are used in the next section.

The Failure Section. SRU arrival is simulated in the next section of the model. Rather than try to fly 100 aircraft (each with 1300 avionic SRUs), an aggregate arrival rate is calculated by summing the individual arrival rates. An individual arrival rate is given by the equation

$$Ra = (1/MTBD) \tag{1}$$

where Ra is the Rate of arrival and MTBD is the Mean Time Between Demand of the SRU. The reciprocal of the Rate of arrival yields the aggregate MTBD for all SRUs on the aircraft:

$$SRU\_MTBD = (1/Ra) \tag{2}$$

SRU_MTBD is the aggregate MTBD of all SRUs and Ra is the aggregate Rate of arrival determined in Eq (1). The SRU_MTBD is one of the key variables in the model since it determines the work load at the depot.

The expected number of SRU arrivals at depot per day can be determined by the equation

$$NO\_FAILURES = FLY\_TIME/SRU\_MTBD \tag{3}$$

where FLY_TIME is the average flying time of all aircraft per day, and SRU_MTBD is computed from Eq (2). The NO_FAILURES is sampled daily from a poisson distribution with a mean calculated by Eq (3). FLY_TIME is computed by dividing the quarterly flying time by 65 flying days per quarter. Although SAC flys on weekends, the base and depot

level maintenance is usually accomplished on weekdays. So for this model, the flying time is divided by the 65 weekdays per quarter. The actual flying time will vary from day to day, but studies have shown that this variance has a negligible impact on failure arrival rates (9).

Another concern is shipping time from each of the four bases to Robbins AFB. The average shipping time from any base to the depot at Robbins AFB is five calender days with an exponential distribution (10). The clock simulates calender days and uses a 48 hour preempt on depot activities to stop work for the weekend. But transportation of shipments is not preempted and still occurs over weekends. The shipments leave the bases at 1600 on weekdays. The actual shipping time may not be five days, but once the system is in steady state, the actual transportation time is important only because it provides an arrival pattern that can be spread out over many days. The exponential shipping times for arriving SRUs from each of the four bases provide this dispersion. They are computed each day for each base. The base of origin is determined on a percentage chance derived from each base's percentage of the total flying time. All of these figures are default variables and can easily be changed at the start of each simulation with a user-friendly input screen.

The avionics SRUs consist of four major types: digital, analog, radio frequency (RF), and microwave (15). Each type has a different average test time on the DATSA and a

different average labor time. The estimated percentage mix of the SRU types and the average times were all provided by the depot at Robbins AFB (15). These figures are also default variables in the model, and they can be easily changed as actual data replaces estimated data. Before being shipped in the simulation, each SRU is marked by type and repair and test times are assigned to it.

The Repair Section. The third part of the discrete section of the model simulates the maintenance repair process at the depot. Failed avionic SRUs arrive as inputs to the process. Each SRU is taken by a worker (if one is available) to an available DATSA, and an initial inspection is accomplished to determine the faulty component on the SRU. When the faulty component has been identified, the DATSA is free for other inspections or tests. The worker repairs the SRU,and then tests the SRU again on the DATSA to insure it is working properly. A small percentage of the SRUs will be found to have no faulty components and ReTest OKay (RETOK). Also, some SRUs will need additional repair after the second testing (RETEST). These percentages are default variables. After a part is repaired it is returned to supply for re-issue.

... DATSAs and workers are input variables for ... run. The quantity of each variable at the ... critical input to the simulation. Another ... DATSA DOWN_TIME. This is the number ... DATSA nonavailability because of ... calibration, or other activities. ... performed on the DATSAs as ... hour MTBF for each DATSA and a 1.5

... types of variables -- default ... variables. The default variables have ... assigned by the model, but these values can ... at run time with the use of an input

Default Variables. The default variable values are listed in Table I. The test, labor, and percentage of each SRU type were obtained from the depot at Robbins AFB. The rest of the data was provided by the B1-B SPO. All data is estimated, but because the model uses variables, it can be updated with actual data when it becomes available. The aggregate SRU MTBD can be calculated elsewhere and input as a single value; or an input file containing each individual SRU MTBD can be read by the model, and a new aggregate SRU MTBD can be computed.

TABLE I

Default Variable Values

RATES		TIMES	
RTOK	0.1000	AGG. SRU MTBD (HRS)	5.734
RETEST	0.1500	DATSA MTBF (HRS)	167.5
PERCENT DYESS	0.2929	DATSA MTTR (HRS)	1.5
PERCENT ELSWORTH	0.3535	ANALOG TEST (MIN)	69
PERCENT GRAND FORKS	0.1768	ANALOG LABOR (MIN)	660
PERCENT MCCONNEL	0.1768	DIGITAL TEST (MIN)	39
PERCENT ANALOG	0.6000	DIGITAL LABOR (MIN)	420
PERCENT DIGITAL	0.3000	RF TEST (MIN)	180
PERCENT RF	0.1000	RF LABOR (MIN)	900
PERCENT MICROWAVE	0.0000	MICRO TEST (MIN)	180
		MICRO LABOR (MIN)	900
		QUARTERLY FLY TIME	7875

TABLE II

Input Variables

NUMBER OF DATSAS
NUMBER OF WORKERS
WARM UP TIME (IN DAYS)
RUN TIME (IN DAYS)
NUMBER OF REPETITIONS
ADDITIONAL SRU LOAD (DAILY)
TOTAL DATSA DOWNTIME (HRS/DAY)

Input Variables. The input variables do not have default settings, so they must be input at run time. Table II lists the input variables. The number of DATSAs is the variable of major concern, and its value was varied to determine the results using different quantities of DATSAs. The number of workers is a value determined by the production labor specialist based on their estimate of the anticipated workload (15). The warm up time is the number of days the simulation is to run to achieve steady state conditions. A value three times the transportation time is usually sufficient for warm up and this value was tested and used in the simulations. The run time is the number of days the model is to simulate the process. For all simulations a run time of 90 days (one quarter) was used to insure a sufficiently large enough run time as discussed below.

The number of repetitions is the number of times the model is to repeat a simulation run with out resetting simulation variables or entities. This produces the effect of one long simulation run with data collected in intervals called "batches." The mean values in these repetitions or "batches" are not independent, but if the run time of the repetition is sufficiently large, then the means can be considered as independent because the bias in the variance estimator will be approximately one (2:440). Additional SRU load is the number of additional faulty SRUs created daily. It can be used for sensitivity analysis dealing with an increased SRU load on the depot. Total DATSA downtime is

the number of hours per day of total DATSA nonavailability for preventive maintenance, calibration, or other uses. All simulations used a DATSA downtime of 30 minutes per available DATSA per day.

<u>Common Random Number Streams</u>

Common random number streams were utilized to synchronize the simulations for comparison purposes. The resulting correlated sampling helped achieve variance reduction for smaller confidence intervals. "Correlated sampling means that, for each replication, the same random numbers are used to simulate both systems" (2:456). Since the number in the random stream when the next repetition begins is not the same as the one that started the preceding repetition, and the run length is sufficiently large (90 days), then the repetitions can be considered independent. Also, since the random numbers are synchronized in the model, the next repetition of each series of runs (or experiments) will be the same (2:456-457). Thus different test are correlated and variance reduction is achieved.

Ninety-five percent confidence intervals were used for all experiments. This means that, statistically speaking, 95 percent of all observations should occur within this measurement interval. In the case where one system is being compared to another, if the difference in mean values of the variables in question has a confidence interval which includes zero, then no statistical evidence exists for a

difference between the values (with a 95 percent confidence).

Coding

The simulation language is SIMPLE 1, and the simulation will run on any IBM or IBM compatible personal computer. Appendix A contains the documented source code for the model. The SIMPLE 1 simulation environment consists of five main sections: the declare, prerun, discrete, continuous, and postrun sections. User defined global variables, entities, screen layouts, and files are contained in the declare section. The user defined variables help to make the model easier to read and understand. The prerun is used in conjunction with the postrun section to initialize, clear, and reset variables. These two sections also combine to provide the powerful run control features which contribute to user-friendly control of the model (4:5.4). The continuous section is used for continuous simulation models and is not used in this model. The discrete section of the model consists of three main areas: a clock section to simulate a forty hour work week, a failure section to simulate SRUs arriving at depot, and a repair section to simulate the SRU repair process at the depot. Figure 1 shows the main logic flow in the discrete section of the model.

CLOCK

1. SET DAILY VARIABLES
   (SHIPPING TIME AND # OF FAILURES)
2. DELAY FOUR HOURS
3. PREEMPT WORKERS FOR LUNCH (45 MINUTES)
4. DELAY FOUR HOURS
5. PREEMPT WORKERS FOR THE EVENING
6. DELAY 915 MINUTES (UNTIL 0730 THE NEXT DAY)
7. ACCOMPLISH #s 1-6 FIVE TIMES THEN DELAY 48 HOURS
   (WEEKEND DELAY)
8. START AT # 1 AGAIN (0730 MONDAY)

FAILURES (MON - FRI)

1. CREATE THE NUMBER OF SRU FAILURES FOR THE DAY
2. DETERMINE THE BASE OF ORIGIN
3. ASSIGN SHIPPING TIMES ASSOCIATED WITH THE BASE
4. DETERMINE THE TYPE OF SRU
5. ASSIGN TEST AND REPAIR TIMES BASED ON TYPE
6. DELAY FOR DURATION OF SHIPMENT
7. ARRIVE AT DEPOT

REPAIR (MON - FRI)

1. WORKER DOES INITIAL INSPECTION OF SRU ON DATSA
   (IF DATSA FAILS WORKER FIXES DATSA)
2. DATSA RELEASED BACK TO SERVICE
3. WORKER REPAIRS SRU (RTOK SENT TO SUPPLY)
4. WORKER TESTS SRU AFTER REPAIR
   (SOME FAIL TEST AND NEED MORE REPAIR)
5. DATSA RELEASED; SRU SENT TO SUPPLY
6. WORKER GETS ANOTHER SRU OR WAITS FOR ONE
7. START AGAIN AT #1

Figure 1. Logic Flow of Discrete Section

Verification and Validation

Verification and validation are two very important checks that every model must use. Verification means that the computer program of the model is doing exactly what it is supposed to do. Validation means that the simulation model accurately represents the real world system it is simulating (2:14).

Verification was accomplished by building the model in modules, and checking each one against results expected by using equations and computing straight averages. Appendix B contains a standard report generated on one of the test runs of the model. It displays the activity of entities in each labelled node of the model. By comparing the number of entities that passed through each node, the model can be verified to be accomplishing the logic described in Figure 1. The program code is well-documented to assist in verification (2:381).

Model validity is more difficult to demonstrate since objective tests require actual data, and actual data does not exist (2:383). To demonstrate that the model is repre-sentitive of the real world system, subjective tests were used. Subjective tests are easier if the model is built with high face validity (2:384). Face validity was achieved through close working with the users (the SPO). Thorough discussion of the methods and assumptions in the model along with sensitivity analysis of output was maximized, and the final logic was validated with the B1-B SPO (1).

IV. The Analysis and Results

Warm Up Runs

The simulation models the SRU repair process in steady state, so a warm up period was utilized to avoid the low averages associated with the start up period where all processes start empty. Several runs were required to determine the warm up period for steady state operation.

A warm up period equal to three times the transportation delay time should be sufficient for this simulation (9). Since the simulation uses an average transportation delay of five days, the first test was to show there is no statistical difference between the variables of concern (DAYS IN DEPOT, IDLE DATSAS, IDLE WORKERS, and SRUS WAITING) with warm up periods of 15, 20, 25, and 30 days. Four runs were accomplished using each of the four different warm up periods. The lengths of the run after the warm up were 90, 85, 80, and 75 days respectively. This kept the total simulation time (warm up time plus run time) equal for each test. After all four runs were complete, a mean value and standard deviation were computed for each of the four variables of concern. The results of the experiment are contained in Table III.

The values appear to be similar by casual inspection, but to insure no statistical difference, a confidence

TABLE III

Warmup Runs

WARM UP	RUN LENGTH	DAYS IN DEPOT	IDLE DATSAS	IDLE WORKERS	SRUS WAITING
15	90	3.472	2.2	13.9	22.3
20	85	3.282	2.3	14.1	19.6
25	80	3.402	2.1	13.2	19.7
30	75	3.482	2.1	12.6	20.7
MEAN		3.409	2.175	13.450	20.575
STAND. DEV.		0.080	0.083	0.594	1.085
UPPER 95% CI		3.537	2.307	14.395	22.301
LOWER 95% CI		3.282	2.043	12.505	18.849

interval was computed for each of the four variables of concern. The mean values for each test of different warm up periods lies within the confidence interval for each variable. This indicates that there is no evidence of statistical difference between the four different tests. Figs 2,3,4, and 5 graphically show the results. Since no evidence of a difference existed, the smallest value, 15 days, was chosen for the production runs.

Production Runs

Once the warm up period to achieve steady state conditions had been determined, production runs were accomplished using different quantities of DATSAs. Four production runs were accomplished with the only difference being the number of DATSAs. Since the original plan called for 10 DATSAs to be used at the depot, the first test was

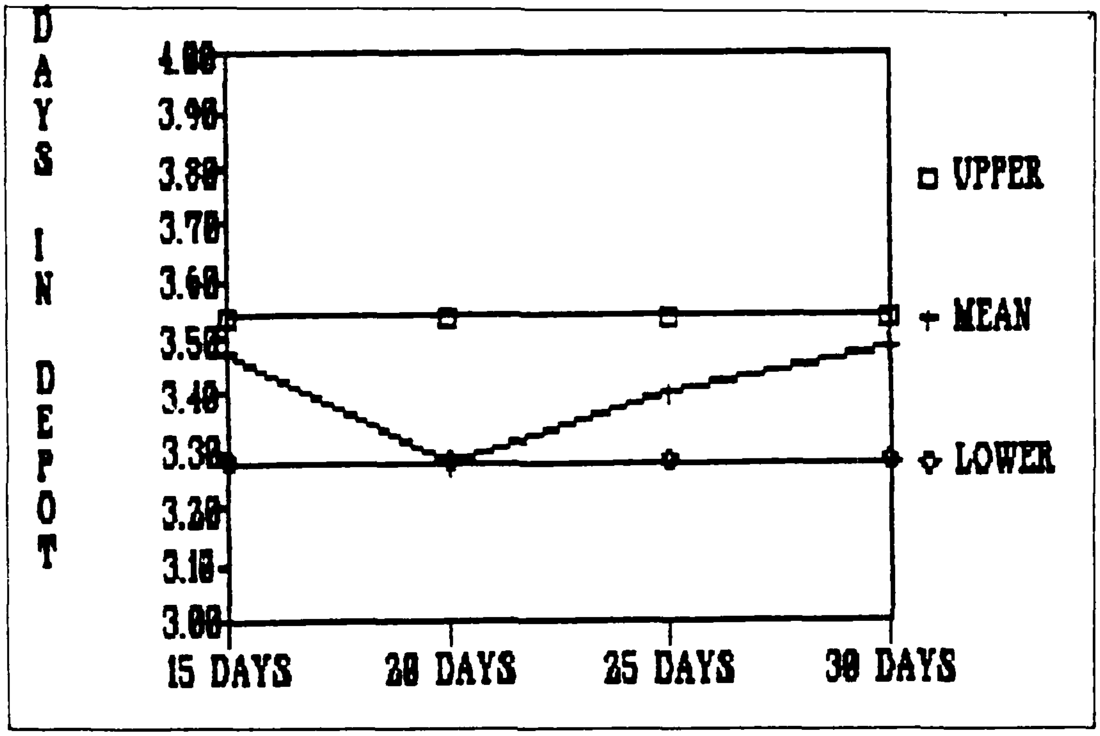

Figure 2. Days in Depot vs Run Length

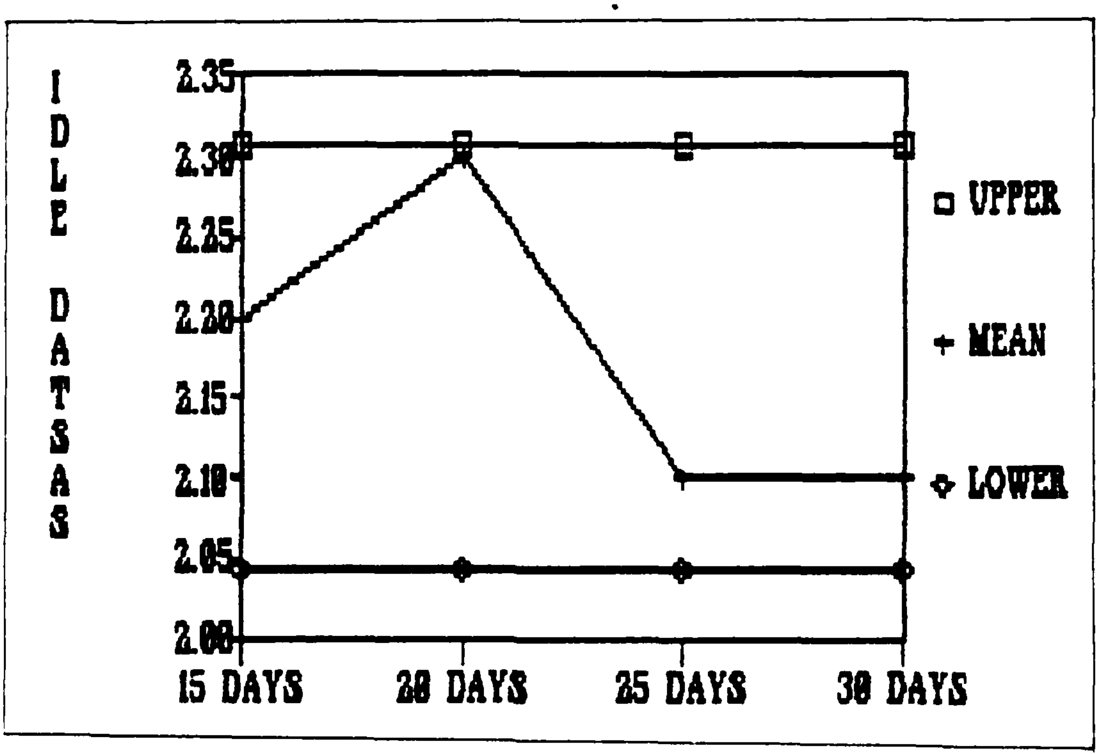

Figure 3. Idle DATSAs vs Run Length

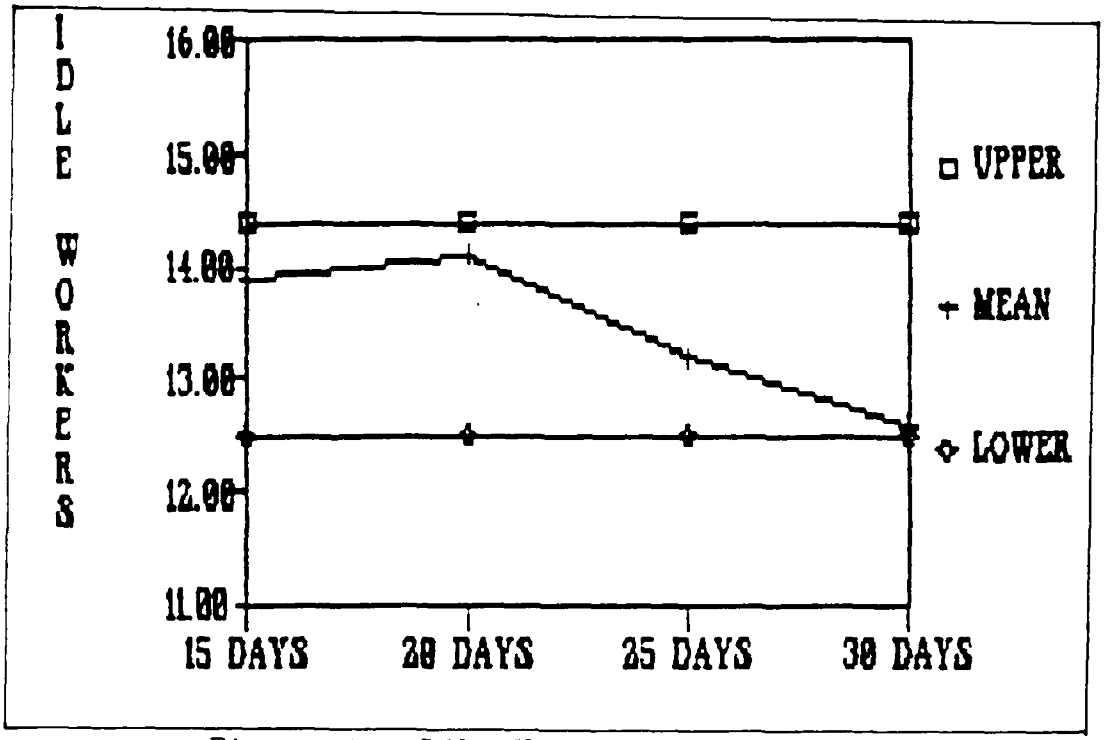

Figure 4. Idle Workers vs Run Length

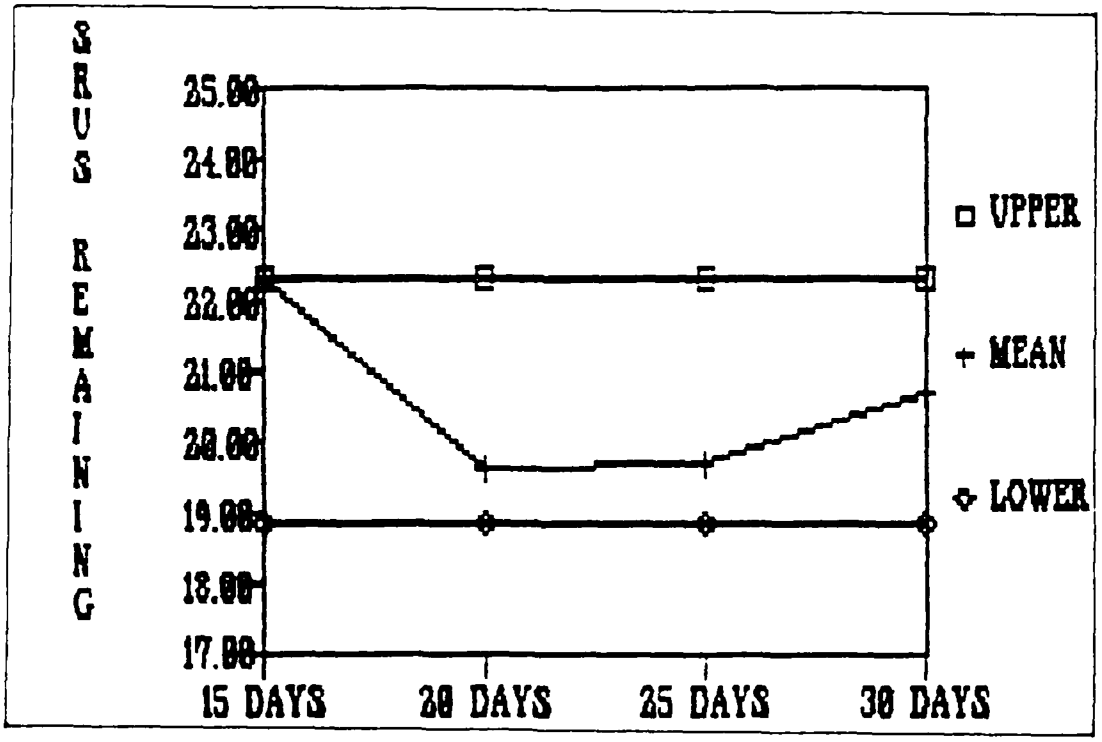

Figure 5. SRUs Remaining vs Run Length

with 10 DATSAs. The results are summarized in Table IV. For all the experiments a warm up time of 15 days and a run time of 90 days was used. The number of available workers was held constant at 50 workers. Each experiment consisted of 5 runs or "batches," and the results were an average of the 5 runs.

<u>Nine DATSAs versus Ten DATSAS</u>. The next test was conducted using nine DATSAs, and the results are also in Table IV. The complete data from each repetition are in Appendix D. The results using 10 and nine DATSAs were compared. The average number of days each SRU spent in the depot increased by .288 days (about 7 hours) when nine DATSAs were used instead of 10. Since the confidence interval (C.I.) does not include zero then the evidence supports the fact that the difference in days in the depot between the two tests is not only attributed to random number possibilities in the simulations.

The average number of idle DATSAs decreased by 1.460 using nine DATSAs, and the C.I. for this number does not include zero. So, no statistical evidence exists to support the fact that the difference between the number of idle DATSAs is only attributed to random possiblilities in the simulations. The DATSA utilization is derived by dividing the average number of stations in use by the number available, or

UTIL = (NUMBER_OF_DATSAS-IDLE_DATSAS)/NUMBER_OF_DATSAS (4)

TABLE IV

Change DATSA Summary

DAYS IN DEPOT

50 WORKERS	10 DATSAS	9 DATSAS	8 DATSAS	9-10 DIFFER	8-9 DIFFER
MEAN	3.114	3.403	4.767	0.288	1.364
STAND. DEV	0.145	0.233	0.553	0.185	0.468
UPPER 95%	3.294	3.692	5.453	0.518	1.946
LOWER 95%	2.935	3.113	4.080	0.059	0.782

IDLE DATSAS

50 WORKERS	10 DATSAS	9 DATSAS	8 DATSAS	9-10 DIFFER	8-9 DIFFER
MEAN	3.880	2.420	0.860	-1.460	-1.560
STAND. DEV	0.337	0.685	0.372	0.422	0.571
UPPER 95%	4.298	3.271	1.322	-0.936	-0.851
LOWER 95%	3.462	1.569	0.398	-1.984	-2.269

IDLE WORKERS

50 WORKERS	10 DATSAS	9 DATSAS	8 DATSAS	9-10 DIFFER	8-9 DIFFER
MEAN	15.740	15.200	13.320	-0.540	-1.880
STAND. DEV	1.435	1.691	0.863	1.080	1.670
UPPER 95%	17.521	17.300	14.392	0.801	0.194
LOWER 95%	13.959	13.100	12.248	-1.881	-3.954

SRUS WAITING

50 WORKERS	10 DATSAS	9 DATSAS	8 DATSAS	9-10 DIFFER	8-9 DIFFER
MEAN	15.480	19.680	40.480	4.200	20.800
STAND. DEV	2.168	3.548	9.828	2.186	7.519
UPPER 95%	18.172	24.084	52.681	6.914	30.134
LOWER 95%	12.788	15.276	28.279	1.486	11.466

The DATSA utilization, using Eq (4), with 10 stations is .612 or 61.2 percent and the utilization with nine stations is .7311 or 73.11 percent.

The average number of idle workers decreased by .540 using nine DATSAs, but the C.I. for this difference does include zero. So the evidence suggests there is no statistical difference between the number of idle workers using 10 or nine DATSAs. Figure 6 demonstates where the confidence intervals lie with respect to zero.

The average number of SRUs waiting for repair at depot increased by 4.2 or 27.13 percent. The C.I. indicates a statistical difference between the number of SRUs in both tests.

<u>Eight versus Nine DATSAs</u>. The next test was conducted by using all the same variables as before, except the number of DATSAs was lowered to eight. The results of the test are also contained in Appendix D, and summarized in Table IV. Figure 7 graphically displays the C.I.s and their relationship to zero.

The average number of days an SRU spends in depot increased by 1.364 days over the number with nine DATSAs. As depicted on the graph in Figure 7, the C.I. does not contain zero, so there is no evidence to support a similarity in the number of days. This increase was a 40 percent increase over the system with nine DATSAs.

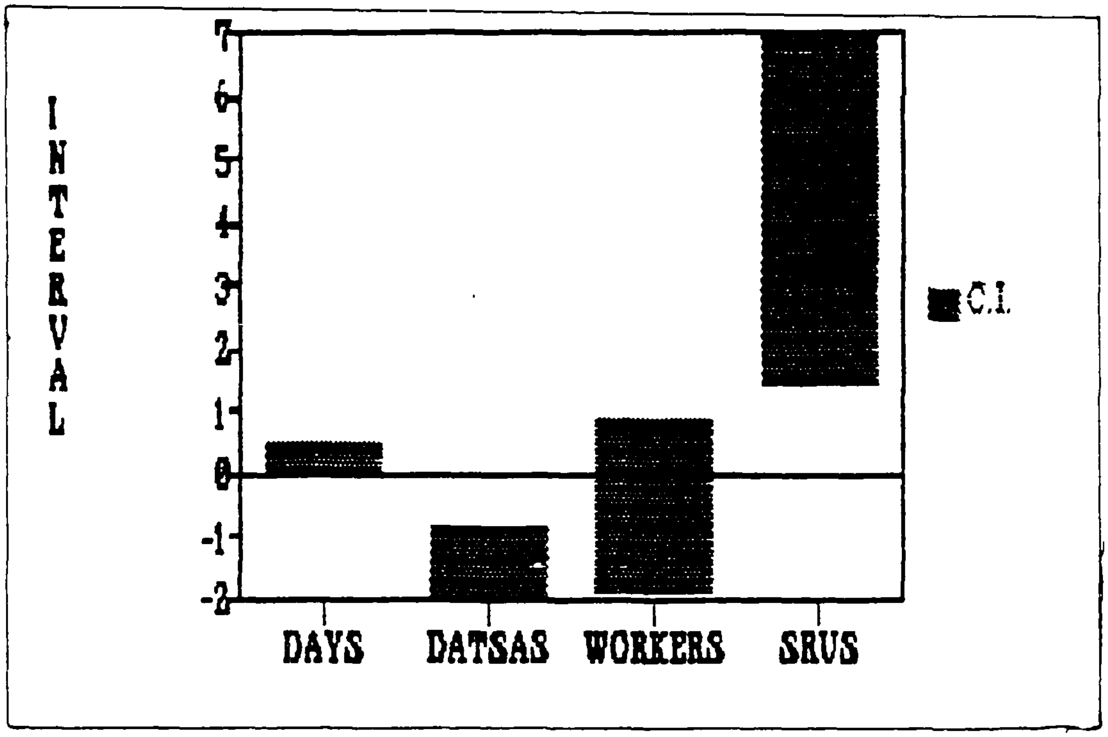

Figure 6. 10 vs 9 DATSAs

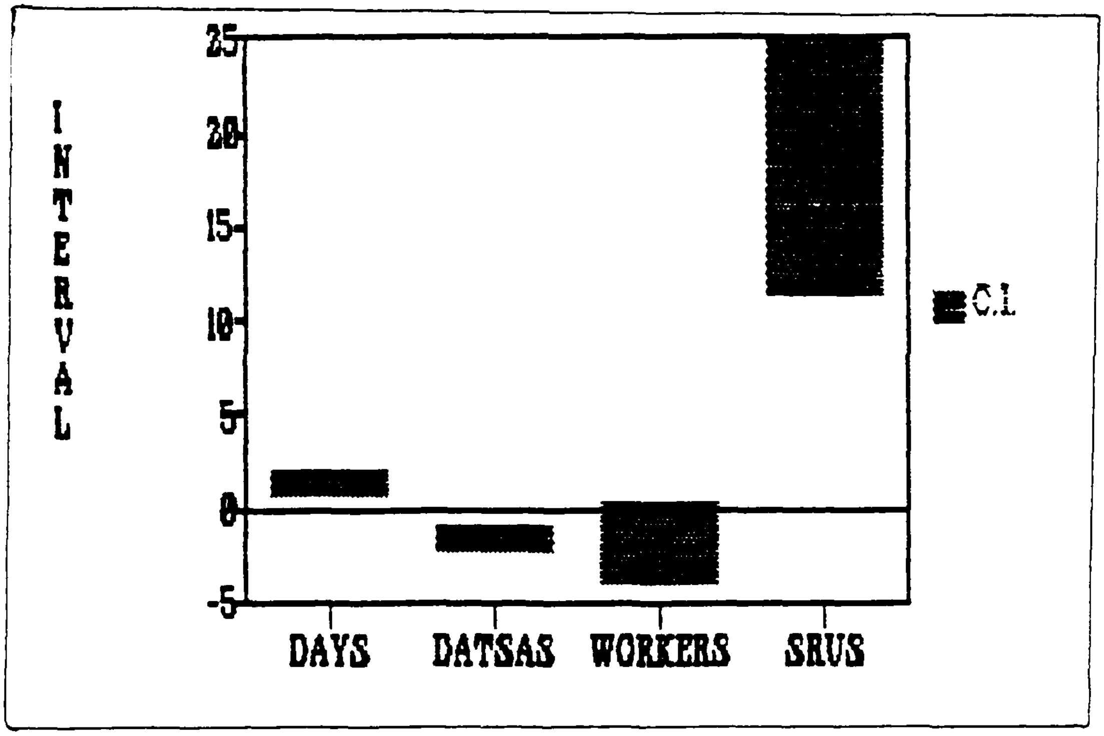

Figure 7. 9 vs 8 DATSAs

The average number of idle DATSAs decreased by 1.56 from the amount using nine DATSAs, and the C.I. did not contain zero, demonstrating a statistical difference. As with the previous test between 10 and nine DATSAs, a number approximately equal to one is at least expected, because the quantity of available DATSAs was decreased by one. Using Eq (4), the DATSA utilization is 89.25 percent, which is close to the 92 percent utilization the SPO would like to achieve (1).

The average number of idle workers decreased by 1.88 after reducing the number of DATSAs from nine to eight. As in the previous test with nine and 10 stations, the C.I. for the number of idle workers contains zero. Therefore, statistical evidence demonstrates there is no difference between the number of idle workers in this test either. It appears that varying the number of DATSAs has little effect on the number of idle workers. The number of available workers was varied as part of a sensitivity analysis and is discussed under that subheading.

The average number of SRUs waiting for repair at the depot increased by 20.8 SRUs or 105.7 percent over the system with nine DATSAs. The C.I. for this difference does not include zero (see Figure 7), so statistical evidence supports the difference between the two quantities is not only caused by random number possibilities in the simulations. Even with a 105 percent increase in SRUs waiting for repair, the system was able to clear out the

excess and not continue to accumulate even large numbers of SRUs to repair. This is good evidence the system is still in steady state.

Seven versus Eight Datsas. Next, the same experiment was conducted but the number of DATSAs was reduced by one to seven. Since the number of idle DATSAs in the system with eight DATSAs was .86, the result was predictable -- steady state conditions were violated and an infinite queue of SRUs awaiting service resulted. Since steady state was violated, no comparisons were necessary with the other systems. However, this test added to the validity of the model by showing that if the number of DATSAs is decreased too far, an infinite queue of SRUs waiting repair will develop.

Sensitivity Analysis

Sensitivity analysis was conducted by changing variables such as the number of workers and the average daily flying time. If these variables are changed drastically to shock the system, and the system fully recovers then it can be considered a "stable" system in equilibrium (11:5). Many other variables could be changed for a sensitivity analysis, but the number of workers and average daily flying time were chosen because they are the variables whose values can be controlled in the "real world" system. Also, the three major inputs to the system are the number of DATSAs available, the number of workers available, and the number of SRUs arriving at the depot for repair.

The average daily flying time is only one of many variables controlling the number of SRUs arriving in the system, thus it is representative of all of these variables.

Number of Workers. A test of the sensitivity of varying the number of workers was conducted by holding all variables constant and changing only the number of available workers for each test. The data obtained from these tests are contained in Appendix E and are summarized in Table V. Since the earlier tests demonstrated that changing the number of DATSAs had a negligible effect on the number of idle workers, the number of DATSAs was held constant at eight for this set of tests.

The first test was to conduct a run with 50 workers and another one with 45 workers. Figure 8 shows that the C.I.s for all variables of concern contain zero, except the C.I. for the number of idle workers. This could be expected to decrease by approximately five workers (the actual number decreased), and it did decrease by 4.72 workers. So statistical evidence indicates no significant difference between the system with 50 workers and the system with 45 workers.

Next, a simulation run using 40 workers was accomplished. This time the number of idle DATSAs remained unchanged, but the number of days in the depot increased by 4.82 or 97.8 percent, and the number of SRUs remaining

TABLE V

Change Worker Summary

DAYS IN DEPOT

8 DATSAS	50 WORKRS	45 WORKRS	40 WORKRS	50-45 DIFFER	45-40 DIFFER
MEAN	4.767	4.928	9.747	-0.161	-4.820
STAND. DEV	0.553	0.518	3.422	0.546	3.611
UPPER 95%	5.453	5.571	13.995	0.516	-0.336
LOWER 95%	4.080	4.285	5.499	-0.838	-9.303

IDLE DATSAS

8 DATSAS	50 WORKRS	45 WORKRS	40 WORKRS	50-45 DIFFER	45-40 DIFFER
MEAN	0.860	0.760	0.760	0.100	0.000
STAND. DEV	0.372	0.388	0.224	0.245	0.316
UPPER 95%	1.322	1.241	1.039	0.404	0.393
LOWER 95%	0.398	0.279	0.481	-0.204	-0.393

IDLE WORKERS

8 DATSAS	50 WORKRS	45 WORKRS	40 WORKRS	50-45 DIFFER	45-40 DIFFER
MEAN	13.320	8.600	3.360	4.720	5.240
STAND. DEV	0.863	0.876	0.484	1.420	0.575
UPPER 95%	14.392	9.688	3.961	6.483	5.954
LOWER 95%	12.248	7.512	2.759	2.957	4.526

SRUS WAITING

8 DATSAS	50 WORKRS	45 WORKRS	40 WORKRS	50-45 DIFFER	45-40 DIFFER
MEAN	40.480	43.340	122.200	-2.860	-78.860
STAND. DEV	9.828	9.004	54.094	7.536	57.677
UPPER 95%	52.681	54.518	189.355	6.496	-7.256
LOWER 95%	28.279	32.162	55.045	-12.216	-150.464

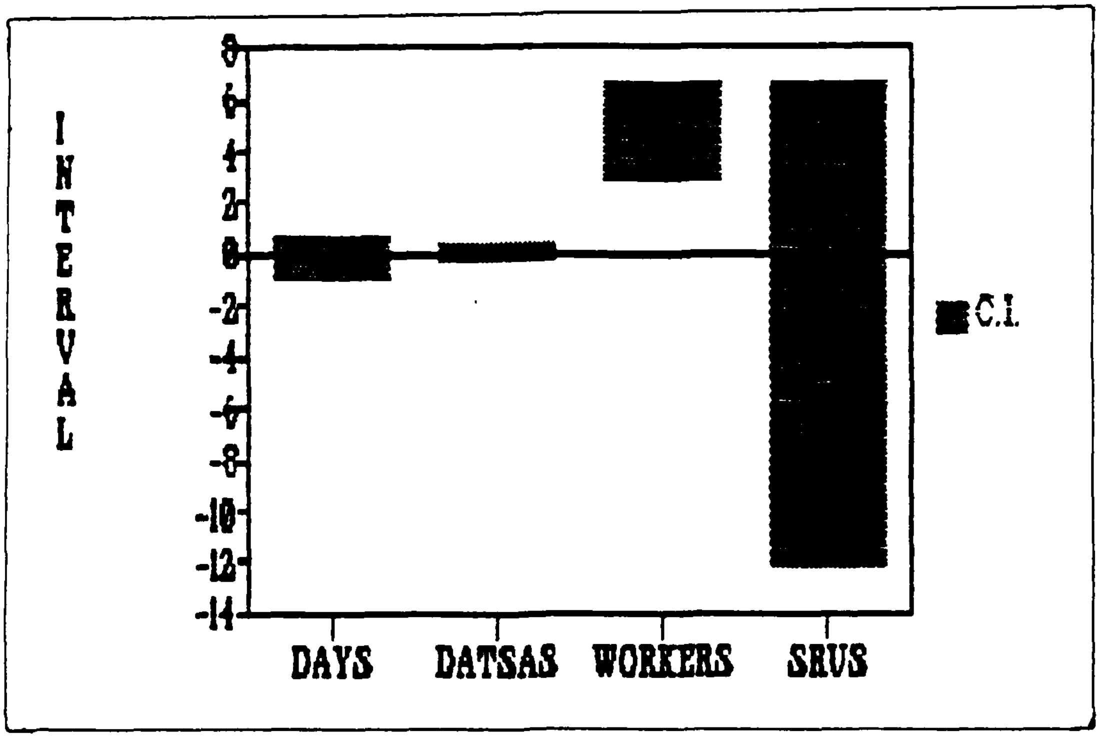

Figure 8. 50 vs 40 Workers

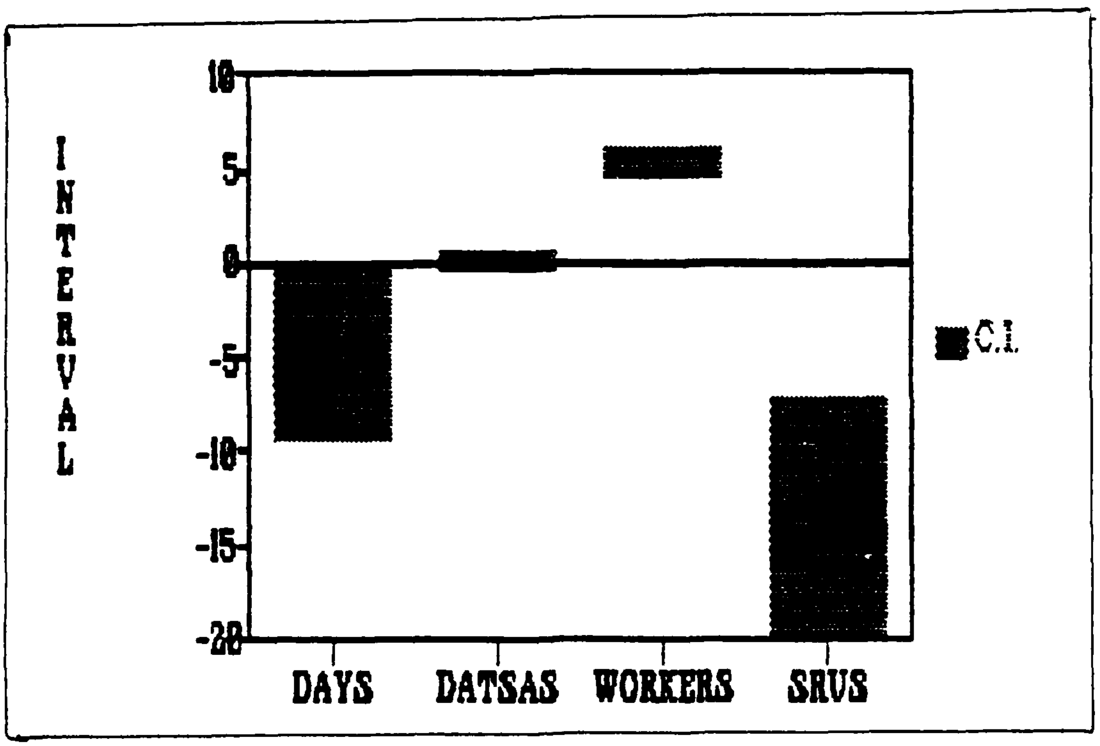

Figure 9. 45 vs 40 Workers

increased by 78.86 or 181 percent. At first, it appeared that steady state had been violated, but the average number of idle DATSAs stabilized at .6 (92.5 percent utilization). The number of SRUs waiting for repair indicated a steady rise (see Appendix E), but another run was accomplished with an additional repetition (6th), and it showed a lower number of SRUs remaining. So the system remained in steady state, but a very large backlog of SRUs accumulated which would probably take a long time to clear out. The evidence seems to indicate that the system with 40 workers is at the boundary line between steady state and infinite queues.

A third test with 35 workers confirmed this idea. Each succeeding repetition accumulated larger and larger numbers of SRUs waiting repair, and DATSA utilization was near 100 percent the entire time.

Flying Time. Another experiment was conducted to test the effect of an increased arrival rate of SRUs at the depot. This was accomplished by increasing and decreasing the average daily flying time by 10 percent. All other variables were held constant with eight DATSAs and 50 workers. The data is contained in Appendix F and summarized in Table VI. A casual look at Figure 10 shows that three of the C.I.s contain zero (or are very close), but the C.I. for SRUs waiting repair indicates a statistical difference between the normal flying time and the 10 percent increase. A closer inspection of SRUs Waiting in Appendix F indicates

TABLE VI

Change Flying Time Summary (8 DATSAs)

DAYS IN DEPOT

8 DATSAS	NORM FLY	+10% FLY	-10% FLY	+10% DIFFER	-10% DIFFER
MEAN	4.802	11.536	3.278	6.734	-1.524
STAND. DEV	0.810	4.800	0.191	4.764	0.670
UPPER 95%	5.807	17.495	3.515	12.649	-0.692
LOWER 95%	3.796	5.577	3.041	0.820	-2.356

IDLE DATSAS

8 DATSAS	NORM FLY	+10% FLY	-10% FLY	+10% DIFFER	-10% DIFFER
MEAN	0.700	0.180	2.280	-0.520	1.580
STAND. DEV	0.502	0.117	0.479	0.412	0.397
UPPER 95%	1.323	0.325	2.875	-0.009	2.073
LOWER 95%	0.077	0.035	1.685	-1.031	1.087

IDLE WORKERS

8 DATSAS	NORM FLY	+10% FLY	-10% FLY	+10% DIFFER	-10% DIFFER
MEAN	12.640	10.840	19.080	-1.800	6.440
STAND. DEV	1.264	1.291	1.883	2.382	1.073
UPPER 95%	14.210	12.443	21.418	1.158	7.772
LOWER 95%	11.070	9.237	16.742	-4.758	5.108

SRUS WAITING

8 DATSAS	NORM FLY	+10% FLY	-10% FLY	+10% DIFFER	-10% DIFFER
MEAN	40.140	166.260	16.340	126.120	-23.800
STAND. DEV	14.337	83.157	2.310	83.050	12.452
UPPER 95%	57.939	269.497	19.208	229.224	-8.341
LOWER 95%	22.341	63.023	13.472	23.016	-39.259

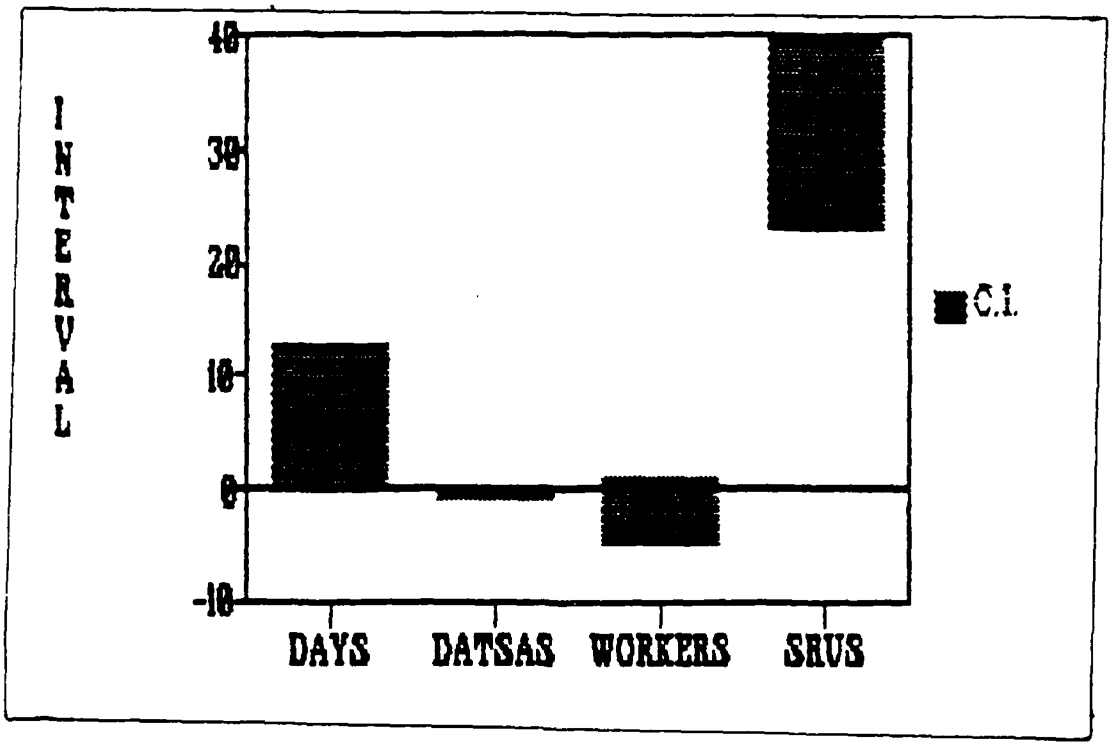

Figure 10. +10% Fly Time With 8 DATSAs

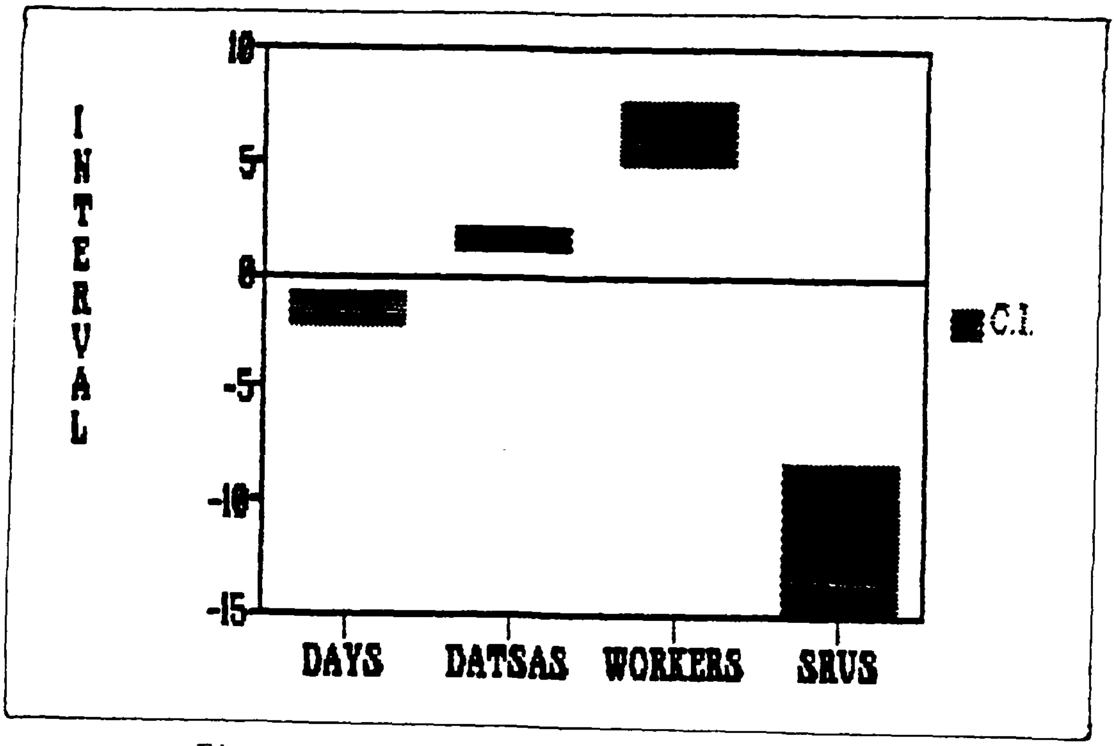

Figure 11. -10% Fly Time With 8 DATSAs

an infinite queue building. This is further indicated by the near zero value of Idle DATSAs.

The test with flying time decreased by 10 percent resulted in all four C.I.s (see Figure 11) not including zero. Therefore, statistical evidence supports the difference between the normal flying time and the lower flying time. Days in depot decreased 1.5 days or 31.7 percent and the number of idle DATSAs increased 1.58 or 225.7 percent over their values with normal flying time.

The increased flying time led to a condition which violated steady state. Therefore, another experiment was conducted varying the flying time by 10 percent with nine DATSAs and 50 workers. The results are also in Appendix F and summarized in Table VII.

Figure 12 shows the C.I.s for days in depot and idle DATSAs contain zero (indicating no support for statistical difference) when the flying time is increased by 10 percent. The average number of idle workers decreased 4.4 workers (29.2 percent) and the average number of SRUs waiting repair increased 13.6 (28.4 percent).

The results of decreasing the flying time by 10 percent are graphically displayed in Figure 13. The results are similar (although opposite in direction) to the test with increased flying time, but the magnitude is not as great. Days in depot only decreased 8.4 percent (versus a 20.9 percent gain with increased flying time), idle DATSAs

TABLE VII

Change Flying Time Summary (9 DATSAs)

DAYS IN DEPOT

9 DATSAS	NORM FLY	+10% FLY	-10% FLY	+10% DIFFER	-10% DIFFER
MEAN	3.403	4.115	3.118	0.712	-0.284
STAND. DEV	0.233	0.515	0.184	0.413	0.330
UPPER 95%	3.692	4.754	3.347	1.226	0.125
LOWER 95%	3.113	3.476	2.889	0.199	-0.694

IDLE DATSAS

9 DATSAS	NORM FLY	+10% FLY	-10% FLY	+10% DIFFER	-10% DIFFER
MEAN	2.420	1.420	3.280	-1.000	0.860
STAND. DEV	0.685	0.668	0.462	0.597	0.900
UPPER 95%	3.271	2.249	3.854	-0.259	1.978
LOWER 95%	1.569	0.591	2.706	-1.741	-0.258

IDLE WORKERS

9 DATSAS	NORM FLY	+10% FLY	-10% FLY	+10% DIFFER	-10% DIFFER
MEAN	15.200	10.760	19.360	-4.440	4.160
STAND. DEV	1.691	2.111	1.717	1.838	1.955
UPPER 95%	17.300	13.380	21.491	-2.158	6.587
LOWER 95%	13.100	8.140	17.229	-6.722	1.733

SRUS WAITING

9 DATSAS	NORM FLY	+10% FLY	-10% FLY	+10% DIFFER	-10% DIFFER
MEAN	19.680	33.260	14.100	13.580	-5.580
STAND. DEV	3.548	9.107	2.280	6.377	3.872
UPPER 95%	24.084	44.567	16.931	21.497	-0.773
LOWER 95%	15.276	21.953	11.269	5.663	-10.387

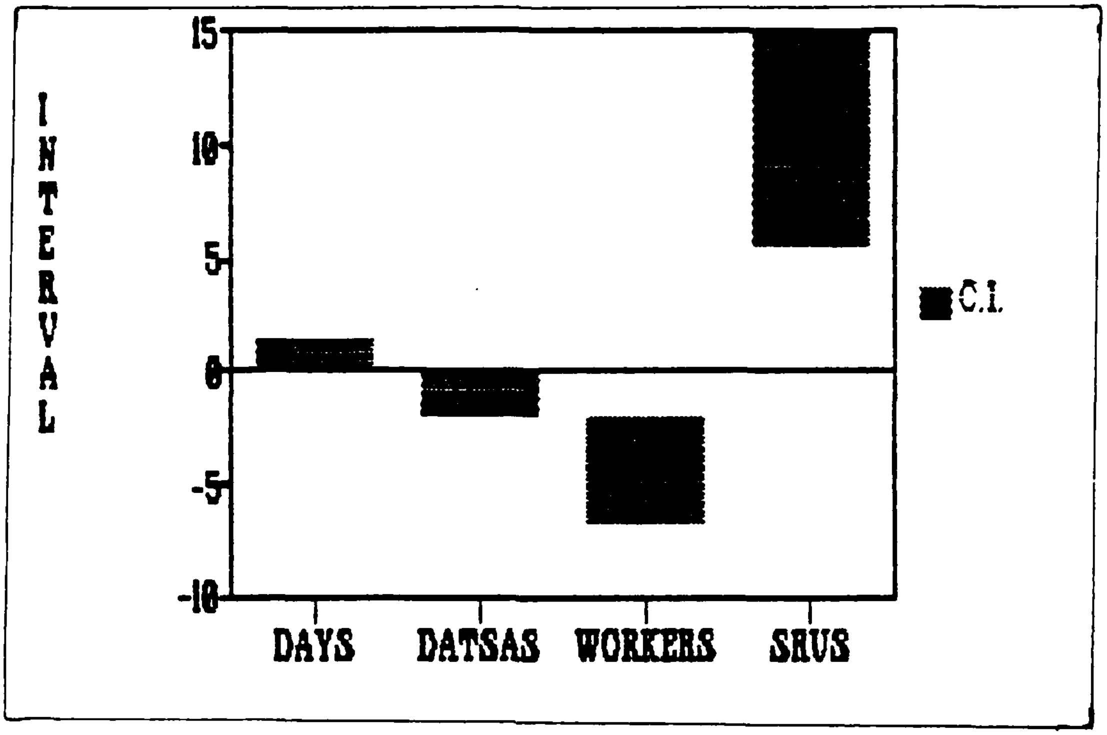

Figure 12. +10% Fly Time With 9 DATSAs

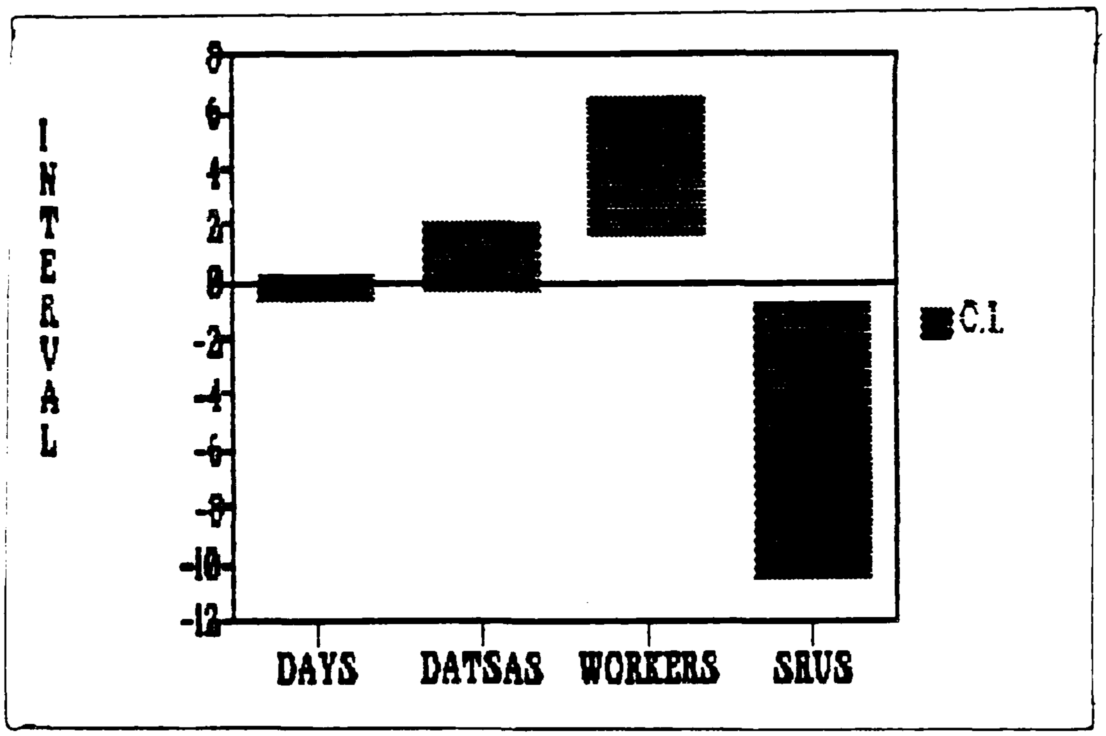

Figure 13. -10% Fly Time With 9 DATSAs

increased 35.5 percent (versus a decrease of 41.3 percent), idle workers increased 27.4 percent (versus a decrease of 29.2 percent), and SRUs waiting repair decreased 28.4 percent (versus an increase of 69 percent). Therefore it appears that with 9 DATSAs steady state conditions can be maintained after varying the average daily flying time by 10 percent. The sensitivity analysis indicates the system seems more sensitive to increasing flying time as opposed to decreasing flying time.

V. The Conclusion and Recommendations

Summary

The specific purpose of this research was to provide recommendations to the B1-B SPO concerning the quantity of computerized test stations (DATSAs) required at the Warner-Robbins Air Logistic Center depot for repair of B1-B avionic SRUs. First data was collected to determine the conditions the "real world" system would be operating under. Then a computer model was developed using the projected operating logic of the actual system. A simulation language, Simple_1, was chosen to provide the simulation environment for the model used in the experiments. Simple_1 was chosen because of its ease of use, flexibility, and availability on personal computers. Then tests were conducted using 10, nine, eight, and seven DATSAs. The results of the four tests are summarized in Table VIII and discussed in the conclusion of this thesis. Next, a sensitivity analysis was conducted by changing the number of workers available and the average daily flying time to study the effects of these variables on the system. The variables when changed enough could cause the system to depart steady state conditions.

TABLE VIII

Summary Chart of Changing DATSA Quantities

Variable	10	vs 9	vs 8
Days (% increase)	--	9.28%	40.08%
DATSA Utilization	61.20%	73.11%	89.25%
Worker Utilization	68.52%	69.60%	73.36%
SRUs Wait (% increase)	--	27.13%	105.69%

Conclusion

The tests conducted to compare different quantities of DATSAs indicate that the B1-B avionic SRU repair system can maintain steady state conditions with as little as eight DATSAs (see Table VIII). When seven DATSAs were tried, the system departed steady state conditions, and an infinite queue of SRUs waiting for repair developed. These results suggest that eight stations may be a viable solution. However, other considerations must be delt with. The number of days a SRU is in the depot only increased nine percent when the number of DATSAs was reduced from 10 to nine. Compare this to the additional 40 percent increase when the number of DATSAs was decreased from nine to eight.

The DATSA utilization when changing from 10 to nine stations increased almost 30 percent to 89.25 percent. This is close to the "perceived" goal of 92 percent by the SPO. But the tests show that in order to achieve this 92 percent utilization, a large number of SRU are kept waiting for repair at the depot. This also results in the 40 percent

increase in the amount of time an SRU spends at the depot. For every SRU waiting in the depot a spare is needed in the field, or the entire weapon system could be unreliable. The impact of a 40 percent increase in the number of days spent in depot could result in a far greater cost to the spares pipeline than the cost of another DATSA.

The sensitivity analysis suggested that eight DATSAs could not respond to a 10 percent increase in flying time and remain within steady state conditions. A similar test with nine DATSAs showed the system was able to absorb the increase and remain within steady state. This strongly suggests the SPO invest in nine DATSAs to (1) provide some flexibility in responding to changing flying times and (2) to minimize (or at least decrease) the dollar investment in spare SRUs.

The other sensitivity analysis tested changing the number of workers at the depot. The depot repair system was simulated with 50 workers for all test runs except during the runs testing the sensitivity of workers. Fifty workers were used to saturate the DATSAs so any delay in the depot would be caused by the lack of a DATSA not the lack of a worker. When the number of workers was decreased to 45, there seemed to be little if any significant difference. But when the number of workers was further decreased to 40, a large number of SRUs were waiting for repair and the system was close to departing steady state. This experiment

demonstrates the importance of the number of workers on the time a SRU spends in depot.

Recomendations

No computer simulation can derive "the" best solution. The results of this research concluded that eight DATSAs could support the SRU repair process at the Warner-Robbins depot. However further analysis of the results indicated that in order to use the minimum number of DATSAs, a high price had to be paid. That price is the cost of delaying many more SRUs (40 percent) in the depot than with nine stations. This is a decision the SPO will have to weigh in making the determination of the number of DATSAs to use at the depot. The author recommends the SPO use this model to simulate the anticipated repair activities at the other depots. The number of DATSAs required elsewhere could also have an impact on this decision. Also, other weapon systems are considering using the same DATSA for some of their avionic SRUs. The model could be run again with increased numbers of SRUs at the depot.

Implementation. The objective of this research is to provide the SPO with the model and results. It will be up to them to see it is fully implemented. The simulation only helps provide the decision maker with several "what ifs?". The final decision is a result of all inputs to the decision maker, not just the results of a simulation.

Future Applications and Revisions. A useful by-product of this research is the computer model which can be run on any IBM or IBM compatible personal computer. The model could be further refined to incorporate the associated costs of DATSAs, workers, and the SRU pipeline. This would provide cost analysis data that would be helpful to the overall decision of the quantity of stations. As stated before, the model is extremely flexible and could be adapted to other similar problems.

Appendix A: Source Code of Model

```
{B1-B DATSA STATION LOADING MODEL (FINAL VERSION)}

DECLARE;

   GLOBALS: DAY:                           {DAY OF THE WEEK COUNTER}
            WORK:                          {FLAG: 1=WORK,0=NO WORK}
            NO_WORKERS:                    {# WORKERS AVAILABLE}
            NO_DATSAS:                     {# DATSAS AVAILABLE}
            RTOK:                          {RETEST OKAY RATE}
            RETEST:                        {RATE FAILING 1ST REPAIR}
            DYESS_TIME:                    {SHIPPING TIME FROM DYESS}
            ELS_TIME:                      {      "          ELSWORTH}
            GRAND_TIME:                    {      "          GRAND FORKS}
            MCON_TIME:                     {      "          MCCONNEL}
            NO_FAILURES OBSERVE_STATS:     {AVE # OF SRU FAILURES PER DAY}
            DELAY_TIME:                    {DURATION OF PREEMPTS}
            REL_RATE:                      {RELIABILITY OF DATSAS}
            DAT_MTBF:                      {MTBF OF DATSAS}
            DAT_MTTR:                      {MEAN TIME TO REPAIR FOR DATSAS}
            TRANS_TIME:                    {AVE # OF DAYS FROM BASE TO DEPOT}
            SRU_MTBD:                      {AGGREGATE MTBD FOR ALL SRUS}
            FLY_TIME:                      {AVE DAILY FLYING HOURS}
            INDEX:                         {MENU SELECTOR}
            NO_DAYS:                       { # OF DAYS OF SIMULATION}
            ANA_TEST_TIME:                 {ANALOG TEST TIME IN MINUTES}
            ANA_LABOR_TIME:                {ANALOG FIX TIME IN MINUTES}
            DIG_TEST_TIME:                 {DIGITAL TEST}
            DIG_LABOR_TIME:                {DIGITAL FIX}
            RF_TEST_TIME:                  {RF TEST}
            RF_LABOR_TIME:                 {RF FIX}
            MICRO_TEST_TIME:               {MICROWAVE TEST}
            MICRO_LABOR_TIME:              {MICROWAVE LABOR}
            RUN_TIME:                      {LENGTH OF SIM IN DAYS}
            IDLE_DATSAS TIME_STATS:        { # OF DATSAS NOT IN USE}
            IDLE_WORKERS TIME_STATS:       { # OF WORKERS NOT IN USE}
            SRUS_WAITING TIME_STATS:       { # OF SRUS AWAITING REPAIR}
            MAX_DATSAS:                    {MAX # OF DATSAS AVAILABLE}
            MAX_WORKERS:                   {MAX # OF WORKERS AVAILABLE}
            ADD_SRUS:                      {ADDITIONAL SRUS TO REPAIR PER DAY}
            INSP_TIME:                     {COMPUTED INSPECTION TIME (MINUTES)}
            FIX_TIME:                      {COMPUTED LABOR TIME IN MINUTES}
            TEST_TIME:                     {COMPUTED TEST TIME IN MINUTES}
            TIME_IN_DEPOT OBSERVE_STATS:   {TOTAL TIME IN DEPOT}
            INSP_WAIT_TIME:                {ACTUAL TIME FOR INSPECTION}
            BIN_WAIT_TIME OBSERVE_STATS:   {TIME WAITING FOR INSPECTION}
            FIX_WAIT_TIME:                 {ACTUAL LABOR TIME FOR REPAIR}
            TEST_WAIT_TIME:                {ACTUAL TIME FOR TEST}
            D_FIX:                         {DATSA REPAIR TIME}
            T_FIX:                         {MORE DATSA REPAIR TIME}
            WARM_UP:                       {WARM UP DURATION IN DAYS}
            REPS:                          {CURRENT REPTITIONS}
            NO_REPS:                       {TOTAL NUMBER OF REPITITIONS}
            DAY_TIME:                      {RUN TIME IN DAYS}
            DOWN_DATSAS:                   {DATSAS NOT AVAILABLE}
            DOWN_TIME:                     {TOTAL DATSA DOWNTIME IN HRS}
            DOWN_MIN:                      {DOWNTIME FOR EACH NONAVAIL DATSA}
            CHAIN:                         {FLAG TO CHAIN}
            DUMMY:                         {FOR INITIALIZING RANDOM SEEDS}
            PER_ANA:                       { % OF SRUS THAT ARE ANALOG}
            PER_DIG:                       { % OF SRUS THAT ARE DIGITAL}
            PER_RF:                        { % OF SRUS THAT ARE RF}
                                           { REST ARE MICROWAVE}
            VALUE:                         {SRU MTBD INPUT READ VARIABLE}
            NO_TIMES:                      {# OF TIMES A MTBD IS USED}
```

```
        INVERSE:                    (RECIPROCAL OF MTBD)
        SELECT:                     (VARIABLE TO INDICATE MENU SELECTIONS)
        DEFARRA(18);                (DEFAULT INPUT VARIABLES STORAGE)

 ENTITIES: CONTROL(2):SRU(5):WORKER(1):DATSA(1);

        (TITLE SCREEN)
DEF_SCREEN: TITLE_SCREEN,20,3,40,15,YES;
+                                          +

      DATSA STATION LOADING MODEL

 SRU AGGREGATE MTBD (IN HRS)=

   1.  OK TO CONTINUE
   2.  CHANGE SRU MTBD
   3.  READ INPUT SRU MTBD FILE
   4.  QUIT

 CHOICE

+                                             +

        (DEFAULT SCREEN)
  DEF_SCREEN: DEFAULT_SCREEN,1,1,60,24,YES;
+                                                            +
                     DEFAULT CONSTANTS
 1.  AGGREGATE SRU MTBD . . . . . . . . . . .
 2.  AVE DAILY FLYING HRS OF ALL A/C. . . .
 3.  AVE TRANSPORT DAYS FROM BASE TO DEPOT.
 4.  DATSA MTBF (HOURS) . . . . . . . . . .
 5.  DATSA MTTR (HOURS) . . . . . . . . . .
 6.  SRU RETEST OKAY RATE (RTOK)  . . . . .
 7.  RATE OF SRUS FAILING TEST AFTER REPAIR
 8.  PERCENT ANALOG SRUS  . . . . . . . . .
 9.  PERCENT DIGITAL SRUS . . . . . . . . .
 10. PERCENT RF SRUS (REMAINDER ARE MICRO).
 11. AVE ANALOG TEST TIME (MINUTES) . . . .
 12. AVE ANALOG LABOR TIME (MINUTES). . . .
 13. AVE DIGITAL TEST TIME (MINUTES). . . .
 14. AVE DIGITAL LABOR TIME (MINUTES) . . .
 15. AVE RF TEST TIME (MINUTES) . . . . . .
 16. AVE RF LABOR TIME (MINUTES). . . . . .
 17. AVE MICROWAVE TEST TIME (MINUTES). . .
 18. AVE MICROWAVE LABOR TIME (MINUTES) . .

    ENTER 0 TO CONTINUE OR # TO CHANGE
+                                                            +

 DEF_SCREEN: BLANK_SCREEN,1,1,60,24,NO;
```

```
        (DISPLAY SCREEN)

  DEF_SCREEN: PICTURE,15,1,51,20,YES;
+                                                    +

                                          DOWN TIME=
                     DATSA SRU REPAIR       #DATSAS=
     REP#                                  #WORKERS=
                                           ADD.SRUS=
                      #SRUS TO REPAIR      RUN TIME=
                                          # OF RUNS=
    DAY#         CURNT  AVE  MIN  MAX      WARM UP=


      IDLE DATSAS                 IDLE WORKERS

   CURNT  AVE  MIN  MAX      CURNT  AVE  MIN  MAX


    TIME IN DEPOT     AVE       MIN        MAX
-     IN DAYS)                                         +

              (INPUT VARIABLES SCREEN)

  DEF_SCREEN: MENU_SCREEN,1,4,30,18,YES;
+                                                                            +


                           ----- SRU REPAIR PROBLEM -----


                        INPUT PARAMETER VALUES TO MODEL:

                              1) NUMBER OF DATSAS  :
                              2) NUMBER OF WORKERS :
                              3) WARM UP (DAYS)    :
                              4) RUN TIME (DAYS)   :
                              5) # OF REPS         :
                              6) ADD SRU LOAD (DAILY):
                              7) TOTAL DOWNTIME (HRS/DAY)      :
                              8) 1 TO START OR 0 TO RE-ENTER   :
+

   FILES: IN1,READ: OUT1,APPEND:

END;

PRERUN;
START  SET MAX_DATSAS :=100:              (MAX DATSAS ALLOWED IN MODEL)
           MAX_WORKERS:=400:              (MAX WORKERS ALLOWED IN MODEL)
       BRANCH TINDEX<1),DO_SET:           (IF VARIABLES NOT INITIALIZED DO IT)
            (CHAIN<1),DO_NEXT:            (OTHERWISE SKIP INITIALIZATION)
                     ,DO_CHAIN;           (GOTO HERE IF 1ST REP OF A CHAIN)

DO_SET   SET SRU_MTBD := 5.73369;         (INITIALIZE SRU_MTBD)
TITLE    SCREEN,TITLE_SCREEN,1,1,1;       (1ST SCREEN)
         SHOW,31,5,SRU_MTBD,3,5:          (DISPLAY SRU_MTBD)
         ACCEPT,10,12,SELECT,0,4;         (GET SELECTION)
         BRANCH SELECT=1,DEFAULTS:
                SELECT=2,MT_CHANGE:
                SELECT=3,READ_DATA:
                SELECT=4,FINISH;
MT_CHANGE ACCEPT,30,5,SRU_MTBD,0;         (SUB TO CHANGE SRU_MTBD MANUALLY)
          BRANCH,TITLE;                   (BACK TO 1ST SCREEN)
```

```
READ_DATA SET SRU_MTBD :=0;               (SUB TO READ SRU MTBDs & AGGREGATE)
          OPEN.IN1 AS MTBD_INF;           (USE MTBD.INP FILE)
          WHILE, EOF(IN1) <>1;
             READ,IN1,VALUE:NO_TIMES:/;
             SET INVERSE:=NO_TIMES/VALUE:
                SRU_MTBD:=SRU_MTBD+INVERSE:
          END_WHILE;
          CLOSE.IN1;
          BRANCH.TITLE;
DEFAULTS  SET DEFARRAY(1):=SRU_MTBD:
              DEFARRAY(2):=121.15:        (FLYING TIME)
              DEFARRAY(3):=5:             (TRANSPORTATION TIME)
              DEFARRAY(4):=167.5:         (DATSA MTBF)
              DEFARRAY(5):=1.4:           (DATSA MTTR)
              DEFARRAY(6):=.10:           (SRU RTOK)
              DEFARRAY(7):=.15:           (RATE OF FAILURE AFTER REPAIR)
              DEFARRAY(8):=.5:            ( % ANALOG SRUS)
              DEFARRAY(9):=.5:            ( % DIGITAL SRUS)
              DEFARRAY(10):=0:            ( % RF SRUS, REST ARE MICROWAVE)
              DEFARRAY(11):=69:           (ANALOG TEST TIME)
              DEFARRAY(12):=660:          (ANALOG LABOR TIME)
              DEFARRAY(13):=39:           (DIGITAL TEST TIME)
              DEFARRAY(14):=420:          (DIGITAL LABOR TIME)
              DEFARRAY(15):=180:          (RF TEST TIME)
              DEFARRAY(16):=900:          (RF LABOR TIME)
              DEFARRAY(17):=180:          (MICROWAVE TEST TIME)
              DEFARRAY(18):=900;          (MICROWAVE LABOR TIME)
SHOW_DEF  SCREEN.DEFAULT_SCREEN.1,1,1;    (DISPLAYS DEFAULT VALUES)
          SET NO_TIMES:=1;
          WHILE.NO_TIMES<19;
             SHOW.45,NO_TIMES+2.DEFARRAY(NO_TIMES),4,2;
             SET NO_TIMES:=NO_TIMES+1;
          END_WHILE;
BACK      ACCEPT,42,22,SELECT,0,18;       (GET # OF VARIABLE TO CHANGE)
          BRANCH SELECT=0,ASSIGN:         (IF 0 THEN NO CHANGE)
                       ,CHANGE;           (OTHERWISE CHANGE THAT VARIABLE)
CHANGE     ACCEPT,44.SELECT+2,DEFARRAY(SELECT),0;
           BRANCH,BACK;
ASSIGN     SET                            (ASSIGN DEFAULT VALUES TO VARIABLES)
           SRU_MTBD:=DEFARRAY(1):
           FLY_TIME:=DEFARRAY(2):
           TRANS_TIME:=DEFARRAY(3):
           DAT_MTBF:=DEFARRAY(4):
           DAT_MTTR:=DEFARRAY(5):
           RTOK:=DEFARRAY(6):
           RETEST:=DEFARRAY(7):
           PER_ANA:=DEFARRAY(8):
           PER_DIG:=DEFARRAY(9):
           PER_RF:=DEFARRAY(10):
           ANA_TEST_TIME:=DEFARRAY(11):
           ANA_LABOR_TIME:=DEFARRAY(12):
           DIG_TEST_TIME:=DEFARRAY(13):
           DIG_LABOR_TIME:=DEFARRAY(14):
           RF_TEST_TIME:=DEFARRAY(15):
           RF_LABOR_TIME:=DEFARRAY(16):
           MICRO_TEST_TIME:=DEFARRAY(17):
           MICRO_LABOR_TIME:=DEFARRAY(18);

           SCREEN,BLANK_SCREEN.0,0.1;              (CLEAR SCREEN)
           SCREEN,MENU_SCREEN,,,.15,1;             (VARIABLE INPUT SCREEN)
RUN_MENU   ACCEPT,51,10,NO_DATSAS.1,MAX_DATSAS:
           SET IDLE_DATSAS:=NO_DATSAS;
           ACCEPT,51,11,NO_WORKERS,1,MAX_WORKERS;
           SET IDLE_WORKERS:=NO_WORKERS:
           ACCEPT,51,12,WARM_UP;
           ACCEPT,51,13.DAY_TIME,1;
           SET RUN_TIME:=DAY_TIME*1440;            (CHANGE DAYS TO MINUTES)
           ACCEPT.51,14.NO_REPS,1;
           ACCEPT.53,15,ADD_SRUS,0;
           ACCEPT,52.16.DOWN_TIME,0:
```

```
          ACCEPT,62,17,INDEX;
          BRANCH (INDEX-1),RUN_MENU:              (CHANGE INPUTS IF DESIRED)
                ,NEXT_SCRN;                       (ELSE CONTINUE)
NEXT_SCRN SCREEN,PICTURE,1,1,1:                   (TURN ON DISPLAY SCREEN)
DO_CHAIN  OPEN,OUT1 AS DATSA_OUT;                 (WRITE HEADER TO FILE)
          SET CHAIN:=0;
          CLEAR;
          SET STOP_TIME:=STIME+WARM_UP*1400;     (1ST RUN IS WARM UP)
          WRITE,OUT1,              'DATSA STATION LOADING':/:/:
                    'WARM UP DAYS=':WARM_UP,3,0:'            ':
                    'NUMBER OF DATSAS=':NO_DATSAS,2,0:/:
                    'NUMBER OF REPS=':NO_REPS,2,0:'          ':
                    'NUMBER OF WORKERS=':NO_WORKERS,3,0:/:
                    'RUN LENGTH=':DAY_TIME,3,0:'             ':
                    'ADDITIONAL SRUS=':ADD_SRUS,2,0:/:
                    'DATSA DOWNTIME (HRS/DAY)=':DOWN_TIME,2,1:/;
          CLOSE,OUT1;
          SET REPS:= 0:
              NO_DAYS:= -WARM_UP;                 (1ST RUN IS WARM UP)
          SHOW,47,9,WARM_UP,3,0;

        (INITIALIZE RANDOM SEED STREAMS)

          SET DUMMY:=SEED(4652,1):       (INSP TIME)
              DUMMY:=SEED(6548,2):       (LABOR TIME)
              DUMMY:=SEED(9471,3):       (TEST TIME)
              DUMMY:=SEED(2748,4):       (DATSA MTTR)
              DUMMY:=SEED(3294,5):       (DYESS SHIPPING TIME)
              DUMMY:=SEED(1473,6):       (ELS SHIPPING TIME)
              DUMMY:=SEED(6912,7):       (GRAND SHIPPING TIME)
              DUMMY:=SEED(7831,8):       (MCCONNEL SHIPPING TIME)
              DUMMY:=SEED(5129,9);       (NO_FAILURES)

          BRANCH,CONT;                   (SKIP NEXT BLOCK ON WARM UP RUN)

DO_NEXT   SET REPS:=REPS+1:              (INCREMENT REPS FOR ADD. RUNS)
              NO_DAYS:=1:                (RESET NO_DAYS)
              STOP_TIME:=STIME+RUN_TIME: (RESET STOP TIME FOR NEXT RUN)
          CLEAR;                         (CLEAR STATS)
CONT      SHOW,7,6,REPS,2,0;
          SHOW,6,10,NO_DAYS,3,0;
          SHOW,47,7,DAY_TIME,3,0;
END;


DISCRETE;

                    (CONTROL CLOCK)

          CREATE,1,CONTROL,,,1:          (START THE CLOCK)
MON       SET DAY := 1;                  (MONDAY)
MORN      SET DYESS_TIME := EXPON(TRANS_TIME,5)*1440: (SHIPPING TIME)
             ELS_TIME := EXPON(TRANS_TIME,6)*1440: (SHIPPING TIME)
             GRAND_TIME := EXPON(TRANS_TIME,7)*1440: (SHIPPING TIME)
             MCON_TIME := EXPON(TRANS_TIME,8)*1440: (SHIPPING TIME)
                        (COMPUTE THE DAILY NUMBER OF FAILURES)
             NO_FAILURES := ROUND(POISSON((FLY_TIME/SRU_MTBD),9))+ADD_SRUS:
             WORK := 1;                  (WORK FLAG ON)
          SHOW,6,10,NO_DAYS,3,0;
          SHOW,47,3,DOWN_TIME,2,1;
          SHOW,47,4,NO_DATSAS,3,0;
          SHOW,47,5,NO_WORKERS,3,0;
          SHOW,47,6,ADD_SRUS,3,0;
          SHOW,47,8,NO_REPS,3,0;
          SET DOWN_DATSAS:=ROUND(DOWN_TIME/8+.5):
              DOWN_MIN:=DOWN_TIME*60/DOWN_DATSAS;
          CLONE,DOWN_DATSAS,DOWN_SHOP;
          ACTIVITY 240;                  (0730-1130)
          CLONE,1,DISPLAY;               (UPDATE DISPLAY)
```

```
        CLONE,NO_WORKERS,TIME_OFF;    (MAKE PREEMPTERS FOR LUNCH)
        SET DELAY_TIME := 45:         (45 MINUTES FOR LUNCH)
            WORK := 0;                (NO WORK DURING LUNCH)
        ACTIVITY DELAY_TIME;          (EAT LUNCH)
        SET WORK := 1;                (BACK TO WORK)
        ACTIVITY 240;                 (1215-1615)
        CLONE,1,DISPLAY:              (UPDATE DISPLAY)
        CLONE,NO_WORKERS,TIME_OFF;    (MAKE PREEMPTERS TO QUIT FOR THE DAY)
        SET DELAY_TIME := 915:        (NIGHT TIME)
            WORK := 0;                (NO WORKING AT NIGHT)
        ACTIVITY DELAY_TIME;          (1615-0730)
        SET DAY:= DAY+1:              (NEXT DAY)
            NO_DAYS:=NO_DAYS+1;
        BRANCH DAY<6,MORN:            (IF NOT WEEKEND, START NEXT WORK DAY)
              1.0,WEND;               (OTHERWISE, BREAK FOR THE WEEKEND)
WEND    CLONE,NO_WORKERS,TIME_OFF;    (MAKE WEEKEND PREEMPTERS)
        SET DELAY_TIME := 2880:       (WEEKEND IN MINUTES)
            WORK := 0:                (NO WORKING ON WEEKENDS)
            NO_DAYS:=NO_DAYS+2;
        ACTIVITY DELAY_TIME;          (0730 SAT. - 0730 MON.)
        BRANCH, MON;                  (NEXT WEEK)

DISPLAY SHOW,17,10,SRUS_WAITING,3,0;
        SHOW,22,10,TIME_AVE(SRUS_WAITING),3,1;
        SHOW,28,10,TIME_MIN(SRUS_WAITING),3,0;
        SHOW,33,10,TIME_MAX(SRUS_WAITING),3,0;
        SHOW,5,16,IDLE_DATSAS,2,0;
        SHOW,10,16,TIME_AVE(IDLE_DATSAS),2,1;
        SHOW,16,16,TIME_MIN(IDLE_DATSAS),2,0;
        SHOW,21,16,TIME_MAX(IDLE_DATSAS),2,0;
        SHOW,29,16,IDLE_WORKERS,3,0;
        SHOW,34,16,TIME_AVE(IDLE_WORKERS),3,1;
        SHOW,40,16,TIME_MIN(IDLE_WORKERS),3,0;
        SHOW,45,16,TIME_MAX(IDLE_WORKERS),3,0;
        BRANCH MAX_NUM(SUPPLY)=0,TERM:
                          ,SHOW_DEP;
SHOW_DEP SHOW,20,19,OBSERVE_AVE(TIME_IN_DEPOT)/1440,4,3;
        SHOW,30,19,OBSERVE_MIN(TIME_IN_DEPOT)/1440,4,3;
        SHOW,40,19,OBSERVE_MAX(TIME_IN_DEPOT)/1440,5,3;
        KILL;

            (DECREASES # DATSAS AVAILABLE FOR DOWN TIME)


DOWN_SHOP QUEUE,FIFO;
            CONDITIONS,,
              SHOP,NUM(SHOP)>MAX_DATSAS-NO_DATSAS,DOWN_ACT:
              DOWN_SHOP.WORK=1,DOWN_ACT;
DOWN_ACT SET IDLE_DATSAS:=IDLE_DATSAS-1;
        ACTIVITY DOWN_MIN;
        SPLIT,DATSA,1,EN_SHOP;
        KILL;

                        (PREEMPTS)

TIME_OFF BRANCH NUM(INSP)>0,INSP_PRE: (PREEMPT INSPECTIONS)
              NUM(FIX)>0,FIX_PRE:    (PREEMPT SRU REPAIRS)
              NUM(TEST)>0,TEST_PRE:  (PREEMPT SRU TESTING)
              NUM(DATSA_FIX)>0,DFIX_PRE:(PREEMPT DATSA REPAIR)
              NUM(TEST_FIX)>0,TFIX_PRE: (PREEMPT DATSA REPAIR)
              1.0,NONE;              (OTHER PREEMPTERS NOT NEEDED)
INSP_PRE PREEMPT,INSP,1,CONTROL(2);  (PREEMPT & STORE REMAIN TIME)
        ACTIVITY DELAY_TIME;          (PREEMPT DURATION)
        SET INSP_TIME:=CONTROL(2);    (RESET INSP TIME)
        SPLIT,CONTROL,1,NONE;         (SEPARATE PREEMPTER)
        BRANCH, INSP;                 (RETURN TO WORK)
```

```
FIX_PRE   PREEMPT,FIX,1,CONTROL(2);      {PREEMPT & STORE REMAIN TIME}
          ACTIVITY DELAY_TIME;           {PREEMPT DURATION}
          SET FIX_TIME:=CONTROL(2);      {RESET FIX TIME}
          SPLIT,CONTROL,1,NONE;          {SEPARATE PREEMPTER}
          BRANCH, FIX;                   {RETURN TO WORK}
TEST_PRE  PREEMPT,TEST,1,CONTROL(2);     {PREEMPT & STORE REMAIN TIME}
          ACTIVITY DELAY_TIME;           {PREEMPT DURATION}
          SET TEST_TIME:=CONTROL(2);     {RESET TEST TIME}
          SPLIT,CONTROL,1,NONE;          {SEPARATE PREEMPTER}
          BRANCH, TEST;                  {RETURN TO WORK}
DFIX_PRE  PREEMPT,DATSA_FIX,1,CONTROL(2);{PREEMPT & STORE REMAIN TIME}
          ACTIVITY DELAY_TIME;           {PREEMPT DURATION}
          SET D_FIX :=CONTROL(2);        {RESET TEST TIME}
          SPLIT,CONTROL,1,NONE;          {SEPARATE PREEMPTER}
          BRANCH, DATSA_FIX;             {RETURN TO WORK}
TFIX_PRE  PREEMPT,TEST_FIX,1,CONTROL(2);{PREEMPT & STORE REMAIN TIME}
          ACTIVITY DELAY_TIME;           {PREEMPT DURATION}
          SET T_FIX :=CONTROL(2);        {RESET TEST TIME}
          SPLIT,CONTROL,1,NONE;          {SEPARATE PREEMPTER}
          BRANCH, TEST_FIX;              {RETURN TO WORK}
NONE      KILL;                          {TERMINATE PREEMPTERS}


                       {SRU FAILURES}

          CREATE,NO_FAILURES,SRU,1440,510;  {SHIP FAILURES AT 1600 DAILY}
SEP       SPLIT: SRU,1,BASE;                {SEPARATE GROUP}
          BRANCH, SEP;

BASE      BRANCH DAY>5,TERM:                {NO FAILURES ON WEEKENDS}
                 .2929,DYESS:               {DYESS FAILURES}
                 .3535,ELS:                 {ELSWORTH FAILURES}
                 .1768,GRAND:               {GRAND FORKS FAILURES}
                 .1768,MCON;                {MCCONNEL FAILURES}

TERM      KILL;                             {VOID WEEKEND FAILURES}

          {STORE SHIPPING TIMES ON SRU ENTITY}

DYESS     SET SRU(2):=DYESS_TIME;
          BRANCH, TYPE;
ELS       SET SRU(2):=ELS_TIME;
          BRANCH, TYPE;
GRAND     SET SRU(2):=GRAND_TIME;
          BRANCH, TYPE;
MCON      SET SRU(2):=MCON_TIME;

          {DETERMINE SRU TYPES & ASSIGN REPAIR TIMES TO SRUS}

TYPE      BRANCH PER_ANA, ANALOG:
                 PER_DIG, DIGITAL:
                 PER_RF, RF:
                      , MICRO;
ANALOG    SET SRU(3) := EXPON(ANA_TEST_TIME,1):
              SRU(4) := EXPON(ANA_LABOR_TIME,2):
              SRU(6) := EXPON(ANA_TEST_TIME,3);
          BRANCH, ARRIVAL;
DIGITAL   SET SRU(3) := EXPON(DIG_TEST_TIME,1):
              SRU(4) := EXPON(DIG_LABOR_TIME,2):
              SRU(6) := EXPON(DIG_TEST_TIME,3);
          BRANCH, ARRIVAL;
RF        SET SRU(3) := EXPON(RF_TEST_TIME,1):
              SRU(4) := EXPON(RF_LABOR_TIME,2):
              SRU(6) := EXPON(RF_TEST_TIME,3):
          BRANCH, ARRIVAL;
MICRO     SET SRU(3) := EXPON(MICRO_TEST_TIME,1):
              SRU(4) := EXPON(MICRO_LABOR_TIME,2):
              SRU(6) := EXPON(MICRO_TEST_TIME,3);
ARRIVAL   ACTIVITY SRU(2);                  {SHIPPING TIME}
          SET SRU(1) := STIME;              {SET TO ARRIVAL TIME}
```

```
ENTER     SET SRUS_WAITING:=NUM(BIN)+1;         {COLLECT STATS ON SRUS WAITING}
BIN       QUEUE,FIFO;                           {WAIT FOR REPAIR HERE}

               {CREATE DATSAS}

          CREATE,1,DATSA,0,0,MAX_DATSAS;     {CREATE # OF DATSAS AVAILABLE}
          BRANCH,SHOP;
EN_SHOP   SET IDLE_DATSAS:=NUM(SHOP)+NO_DATSAS-MAX_DATSAS+1;
SHOP      QUEUE,FIFO;                            {WAIT UNTIL NEEDED}


               {CREATE WORKERS}
          CREATE,1,WORKER,0,0,MAX_WORKERS;      {CREATE # OF WORKERS}
          BRANCH,LOUNGE;
EN_LOUNGE SET IDLE_WORKERS:=NUM(LOUNGE)+NO_WORKERS-MAX_WORKERS+1;
LOUNGE    QUEUE,FIFO;                            {WAIT FOR WORK}
             CONDITIONS,NUM(TEST_BIN)=0 AND NUM(DOWN_SHOP)=0,
                    BIN,WORK=1,COL_BIN:     {GET SRU IF DURING WORK HOURS}
                    LOUNGE,NUM(LOUNGE)>MAX_WORKERS-NO_WORKERS,COL_BIN:
                    SHOP,NUM(SHOP)>MAX_DATSAS-NO_DATSAS,COL_BIN;

               {REPAIR SRUS}

COL_BIN   SET BIN_WAIT_TIME:=STIME-SRU(1):      {GET TIME IN BIN}
              SRU(5):= BIN_WAIT_TIME:           {STORE TIME}
              SRU(1):= STIME:                   {RESET TIME TO START OF REPAIR}
              IDLE_DATSAS:=IDLE_DATSAS-1:       {DEC IDLE DATSAS}
              IDLE_WORKERS:=IDLE_WORKERS-1:     {DEC IDLE WORKERS}
              SRUS_WAITING:=NUM(BIN);           {GET STATS ON WAITING SRUS}

I_TIME    SET INSP_TIME:= SRU(3):               {SET SRU INSPECTION TIME}
              DATSA(1):= DATSA(1)+INSP_TIME:    {ACCUMULATE DATSA USAGE TIME}
              REL_RATE:= EXP(-1/DAT_MTBF/60*DATSA(1));{PROB. OF RELIABLE DATSA}
          BRANCH REL_RATE,INSP:                 {IF RELIABLE THEN INSPECT SRU}
                 1-REL_RATE,D_TIME;             {OTHERWISE, FIX DATSA}

               {BROKEN DATSA}

D_TIME    SPLIT,SRU,1,ENTER:                    {RETURN SRU TO BIN}
          SET D_FIX:=EXPON(DAT_MTTR,4)*60;      {DETERMINE REPAIR TIME}
DATSA_FIX ACTIVITY D_FIX;                       {FIX DATSA}
          SPLIT,WORKER,1,EN_LOUNGE;             {RETURN WORKER TO LOUNGE}
          SET DATSA(1):=0;                      {RESTART DATSA USAGE TIME}
          BRANCH,EN_SHOP;                       {RETURN DATSA TO SHOP}

              {INSPECT SRU}

INSP      ACTIVITY INSP_TIME;                   {USE DATSA TO INSPECT SRU}
          SET INSP_WAIT_TIME:=STIME-SRU(1):     {GET TOTAL TIME FOR INSPECTION}
              SRU(5):=SRU(5)+INSP_WAIT_TIME:    {ADD TO TOTAL DEPOT TIME}
              SRU(1):=STIME;                    {RESET TIME TO START OF REPAIR}
          BRANCH RTOK,SUPPLY:                   {IF TEST OK, THEN FINISHED.
                 1-RTOK,F_TIME;                 {OTHERWISE, FIX SRU}

               {FIX SRU}

F_TIME    SET FIX_TIME:=SRU(4);                 {SET TIME TO FIX SRU}
          SPLIT,DATSA,1,EN_SHOP:                {FREE DATSA FOR OTHER WORK}
FIX       ACTIVITY FIX_TIME:                    {FIX SRU}
          SET FIX_WAIT_TIME:=STIME-SRU(1):      {DETERMINE ACTUAL FIX TIME}
              SRU(5):=SRU(5)+FIX_WAIT_TIME:     {ADD TIME TO TOTAL}
              SRU(1):= STIME;                   {RESET TIME TO START OF TEST}
TEST_BIN  QUEUE,FIFO;                           {WAIT FOR DATSA TO TEST SRU}
            CONDITIONS,NUM(DOWN_SHOP)=0,
                TEST_BIN,WORK=1,T_TIME:         {GET WORKER AND SRU}
                SHOP,NUM(SHOP)>MAX_DATSAS-NO_DATSAS,T_TIME;
```

```
            (TEST SRU AFTER REPAIR)

T_TIME    SET TEST_TIME:=SRU(6):                  (SET SRU TEST TIME)
              DATSA(1):=DATSA(1)+TEST_TIME:       (ACCUMULATE DATSA USEAGE)
              REL_RATE:=EXP(-1/DAT_MTBF/60*DATSA(1)):(DETERMINE RELIABILITY)
              IDLE_DATSAS:=IDLE_DATSAS-1;         (DEC IDLE DATSAS)
          BRANCH REL_RATE,TEST:                   (IF DATSA DOESN'T FAIL, TEST)
                 1-REL_RATE,TF_TIME;              (OTHERWISE FIX DATSA)
TF_TIME   SET T_FIX:=EXPON(DAT_MTTR,4)*60;        (DETERMINE TIME TO FIX DATSA)
TEST_FIX  ACTIVITY T_FIX;                         (REPAIR BROKEN DATSA)
          SET DATSA(1):=0:                        (RESTART DATSA USE TIME)
              IDLE_DATSAS:=IDLE_DATSAS+1;
          BRANCH,T_TIME;                          (TRY TEST AGAIN)
TEST      ACTIVITY TEST_TIME;                     (TEST REPAIRED SRU)
          SET TEST_WAIT_TIME:=STIME-SRU(1):       (DETERMINE TOTAL TEST TIME)
              SRU(5):=SRU(5)+TEST_WAIT_TIME:      (ADD TIME TO TOTAL DEPOT TIME)
              SRU(1):= STIME;                     (RESET TIME)
          BRANCH RETEST,F_TIME:                   (IF TEST FAILED,THEN FIX AGAIN)
                 1-RETEST,SUPPLY:                 (OTHERWISE, SRU REPAIR IS DONE)

SUPPLY    SET TIME_IN_DEPOT:=SRU(5):              (COLLECT TOTAL DEPOT TIME)
          SPLIT,DATSA,1,EN_SHOP;                  (RETURN DATSA TO SHOP)
          SPLIT,WORKER,1,EN_LOUNGE;               (RETURN WORKER)
          KILL;                                   (SRU REPAIR COMPLETE)

END:

CONTINUOUS; END;

POSTRUN;
          OPEN,OUT1 AS DATSA OUT;
          WRITE,OUT1,/:
                    'REP# ':REPS,2,0:/:/:
                    'VARIABLE            CURNT      AVE       MIN':
                    '        MAX    S. DEV':/:':
                    'SRUS WAITING     ':SRUS_WAITING,7,0:' ':
                    TIME_AVE(SRUS_WAITING),7,1: ':
                    TIME_MIN(SRUS_WAITING),7,0:' ':
                    TIME_MAX(SRUS_WAITING),7,0: ':
                    TIME_STD(SRUS_WAITING),7,2:/:
                    'IDLE DATSAS      ':IDLE_DATSAS,7,0: ':
                    TIME_AVE(IDLE_DATSAS),7,1:' ':
                    TIME_MIN(IDLE_DATSAS),7,0: ':
                    TIME_MAX(IDLE_DATSAS),7,0:' ':
                    TIME_STD(IDLE_DATSAS),7,2:/:
                    'IDLE WORKERS     ':IDLE_WORKERS,7,0: ':
                    TIME_AVE(IDLE_WORKERS),7,1:' ':
                    TIME_MIN(IDLE_WORKERS),7,0:' ':
                    TIME_MAX(IDLE_WORKERS),7,0:' ':
                    TIME_STD(IDLE_WORKERS),7,2:/:
                    'DAYS IN DEPOT    ':TIME_IN_DEPOT/1440,7,3:' :
                    OBSERVE_AVE(TIME_IN_DEPOT)/1440,7,3:' ':
                    OBSERVE_MIN(TIME_IN_DEPOT)/1440,7,3: ':
                    OBSERVE_MAX(TIME_IN_DEPOT)/1440,7,3:' ':
                    OBSERVE_STD(TIME_IN_DEPOT)/1440,7,3:/:
                    'INSP WAIT (HRS)  ':BIN_WAIT_TIME/60,7,1:' ':
                    OBSERVE_AVE(BIN_WAIT_TIME)/60,7,2: ':
                    OBSERVE_MIN(BIN_WAIT_TIME)/60,7,1:' ':
                    OBSERVE_MAX(BIN_WAIT_TIME)/60,7,1: ':
                    OBSERVE_STD(BIN_WAIT_TIME)/60,7,2: :/:
          CLOSE,OUT1:
          BRANCH REPS<NO_REPS,NOT_YET:
                           ,FINISH;     (CHANGE LABEL TO 'LOOP' TO CHAIN)

(LABEL LOOP CAN BE USED TO CHANGE INPUT VARIABLES AND RUN AGAIN AUTOMATICALLY)

LOOP      RESET;                          (CLEAR OUT LEFTOVER ENTITIES)
          SET CHAIN:=1:
              NO_DATSAS:=NO_DATSAS-1:
              DOWN_TIME:=DOWN_TIME-.5;
```

```
          BRANCH NO_DATBAS>7,NOT_YET:
                            ,LOOP1;
LOOP1     BRANCH NO_WORKERS=40,FINISH:
                               ,LOOP2;
LOOP2     SET NO_DATBAS:=9:
              NO_WORKERS:=40:
              DOWN_TIME:=4.5;
          BRANCH,NOT_YET;

      {FINISH LABEL USED TO END SIMULATION}

FINISH    SET INDEX:=0;
          STOP;
NOT_YET
END;
```

Appendix B: Simple 1 Standard Report Output

SIMPLE_1

SIERRA SIMULATIONS & SOFTWARE

SUMMARY REPORT FOR: AGG.MDL
GENERATED ON: 7/11/96 5:12pm

SUMMARY REPORT: BLOCK STATISTICS

SIMULATED TIME: STIME = 2.8080000000E+05
STATISTICS CLEARED AT : 1.9440000000E+05

BLOCK LABEL	TYPE	AVERAGE	STD DEV	MIN	MAX	CRNT	CNT
START	SET	0.000	0.000	0	0	0	0
DO_SET	SET	0.000	0.000	0	0	0	0
PLN_MENU	ACCEPT	0.000	0.000	0	0	0	0
NEXT_SCRN	SCREEN	0.000	0.000	0	0	0	0
DO_NEXT	SET	0.000	0.000	0	0	0	0
CONT	SHOW	0.000	0.000	0	1	0	1
MON	SET	0.000	0.000	0	1	0	6
MORN	SET	0.000	0.000	0	1	0	42
WEND	CLONE	0.000	0.000	0	1	0	9
TIME_OFF	BRANCH	0.000	0.000	0	1	0	3800
INSP_PRE	PREEMPT	0.000	0.000	0	1	0	182
FIX_PRE	PREEMPT	0.000	0.000	0	1	0	2446
TEST_PRE	PREEMPT	0.000	0.000	0	1	0	279
DFIX_PRE	PREEMPT	0.000	0.000	0	1	0	18
TFIX_PRE	PREEMPT	0.000	0.000	0	1	0	19
NONE	KILL	0.000	0.000	0	1	0	3765
SEP	SPLIT	0.000	0.000	0	1	0	1260
BASE	BRANCH	0.000	0.000	0	1	0	1260
TERM	KILL	0.000	0.000	0	1	0	352
DYESS	SET	0.000	0.000	0	1	0	262
ELS	SET	0.000	0.000	0	1	0	322
GRAND	SET	0.000	0.000	0	1	0	167
MCON	SET	0.000	0.000	0	1	0	157
TYPE	BRANCH	0.000	0.000	0	1	0	908
ANALOG	SET	0.000	0.000	0	1	0	411
DIGITAL	SET	0.000	0.000	0	1	0	430
RF	SET	0.000	0.000	0	1	0	67
ARRIVAL	ACTIVITY	74.974	16.071	45	117	44	908
ENTER	SET	0.000	0.000	0	1	0	939
BIN	QUEUE	13.005	12.837	0	66	17	1010
SHOP	QUEUE	44.995	2.770	40	50	43	2023
LOUNGE	QUEUE	120.153	9.735	110	138	115	1020
COL_BIN	SET	0.000	0.000	0	1	0	1015
I_TIME	SET	0.000	0.000	0	1	0	1015
D_TIME	SPLIT	0.000	0.000	0	1	0	71
DATSA_FIX	ACTIVITY	0.069	0.305	0	3	0	99
INSP	ACTIVITY	0.680	1.660	0	10	0	1124
F_TIME	SET	0.000	0.000	0	1	0	1003
FIX	ACTIVITY	6.331	11.753	0	39	0	3421
TEST_BIN	QUEUE	0.074	0.347	0	8	0	1005
T_TIME	SET	0.000	0.000	0	1	0	1057
TF_TIME	SET	0.000	0.000	0	1	0	53
TEST_FIX	ACTIVITY	0.051	0.233	0	2	0	71
TEST	ACTIVITY	0.716	1.560	0	10	0	1279
SUPPLY	SET	0.000	0.000	0	1	0	949
FINISH	CLOSE	0.000	0.000	0	1	0	1
NOT_YET	END	0.000	0.000	0	0	0	0

SUMMARY REPORT: OBSERVATIONAL STATISTICS

SIMULATED TIME: STIME = 2.8080000000E+05
STATISTICS CLEARED AT : 1.9440000000E+05

VARIABLE LABEL	TYPE	AVERAGE	STD DEV	MIN	MAX	CRNT	NO.
DYESS_TIME	SCALAR	8018.846	8997.448	91.8	34061.5	6467.3	42
DELAY_TIME	SCALAR	707.368	819.978	45.0	2880.0	2880.0	95
ELS_TIME	SCALAR	5670.554	5176.951	45.1	18969.0	1787.8	42
REL_RATE	SCALAR	0.939	0.044	0.8	1.0	0.8	2072
GRAND_TIME	SCALAR	9112.663	7884.785	446.0	36643.6	13896.7	42
MCON_TIME	SCALAR	7093.897	7563.144	314.9	36083.4	4845.9	42
NO_FAILURES	SCALAR	21.190	4.457	10.0	33.0	10.0	42
SHIPPING_TIME	SCALAR	227358.110	55111.589	91.8	280217.8	280217.8	939
INSP_TIME	SCALAR	67.139	89.197	0.1	895.6	38.6	1195
FIX_TIME	SCALAR	585.819	624.975	0.0	4055.7	9.0	3421
TEST_TIME	SCALAR	66.926	87.798	0.0	763.7	8.8	1332
TIME_IN_DEPOT	SCALAR	3782.534	3328.699	10.7	32111.7	83.4	949
INSP_WAIT_TIME	SCALAR	156.588	497.963	0.1	5503.5	70.6	947
BIN_WAIT_TIME	SCALAR	1091.165	1107.323	0.0	4282.6	68.8	1015
FIX_WAIT_TIME	SCALAR	2075.352	2616.645	0.0	17310.4	54.4	1005
TEST_WAIT_TIME	SCALAR	263.592	652.481	0.0	4609.7	88.4	1005
D_FIX	SCALAR	82.789	78.679	0.0	347.1	209.1	89
T_FIX	SCALAR	82.563	90.198	0.4	453.3	10.4	71

SUMMARY REPORT: TIME PERSISTANT STATISTICS
SIMULATED TIME: STIME = 2.8080000000E+05
STATISTICS CLEARED AT : 1.9440000000E+05

VARIABLE LABEL	TYPE	AVERAGE	STD DEV	MIN	MAX	CRNT
IDLE_DATSAS	SCALAR	3.916	2.726	0.0	9.0	2.0
IDLE_WORKERS	SCALAR	9.645	8.559	0.0	27.0	5.0
SRUS_WAITING	SCALAR	12.999	12.837	0.0	66.0	17.0

Appendix C: Warm Up Data

USING: 9 DATSAS 50 WORKERS 4.5 HOURS DATSA DOWN TIME

WARM UP	RUN LENGTH	DAYS IN DEPOT	IDLE DATSAS	IDLE WORKERS	SRUS WAITING
15	90	3.472	2.2	13.9	22.3
20	85	3.283	2.3	14.1	19.6
25	80	3.402	2.1	13.2	19.7
30	75	3.482	2.1	12.6	20.7
MEAN		3.410	2.175	13.450	20.575
STAND. DEV.		0.079	0.083	0.594	1.085
t .025,3		3.182	3.182	3.182	3.182
UPPER 95% CI		3.536	2.307	14.395	22.301
LOWER 95% CI		3.283	2.043	12.505	18.849

Appendix D: Changing the Number of DATSAs Data

USING: 50 WORKERS

DAYS IN DEPOT

REP #	10 DATSAS	9 DATSAS	9-10 DIFFER		10 DATSAS	9 DATSAS	9-10 DIFFER
1	3.043	3.472	0.429	MEAN	3.114	3.403	0.288
2	3.029	3.392	0.363	STAND. DEV	0.145	0.233	0.185
3	3.381	3.784	0.403	t .025,4	2.776	2.776	2.776
4	3.146	3.072	-0.074	UPPER 95%	3.294	3.692	0.518
5	2.972	3.293	0.321	LOWER 95%	2.935	3.113	0.059

REP #	9 DATSAS	8 DATSAS	8-9 DIFFER		9 DATSAS	8 DATSAS	8-9 DIFFER
1	3.472	4.427	0.955	MEAN	3.403	4.767	1.364
2	3.392	4.105	0.713	STAND. DEV	0.233	0.553	0.468
3	3.784	5.753	1.969	t .025,4	2.776	2.776	2.776
4	3.072	4.799	1.727	UPPER 95%	3.692	5.453	1.946
5	3.293	4.749	1.456	LOWER 95%	3.113	4.080	0.782

IDLE DATSAS

REP #	10 DATSAS	9 DATSAS	9-10 DIFFER		10 DATSAS	9 DATSAS	9-10 DIFFER
1	3.7	2.2	-1.5	MEAN	3.880	2.420	-1.460
2	4.2	2.7	-1.5	STAND. DEV	0.337	0.685	0.422
3	3.3	1.3	-2	t .025,4	2.776	2.776	2.776
4	4.1	3.4	-0.7	UPPER 95%	4.298	3.271	-0.936
5	4.1	2.5	-1.6	LOWER 95%	3.462	1.569	-1.984

REP #	9 DATSAS	8 DATSAS	8-9 DIFFER		9 DATSAS	8 DATSAS	8-9 DIFFER
1	2.2	0.9	-1.3	MEAN	2.420	0.860	-1.560
2	2.7	1.5	-1.2	STAND. DEV	0.685	0.372	0.571
3	1.3	0.4	-0.9	t .025,4	2.776	2.776	2.776
4	3.4	0.9	-2.5	UPPER 95%	3.271	1.322	-0.851
5	2.5	0.6	-1.9	LOWER 95%	1.569	0.398	-2.269

IDLE WORKERS

REP #	10 DATSAS	9 DATSAS	9-10 DIFFER		10 DATSAS	9 DATSAS	9-10 DIFFER
1	15.7	13.9	-1.8	MEAN	15.740	15.200	-0.540
2	16.9	15.5	-1.4	STAND. DEV	1.435	1.691	1.080
3	13.0	12.8	-0.2	t .025,4	2.776	2.776	2.776
4	16.3	17.6	1.3	UPPER 95%	17.521	17.300	0.801
5	16.8	16.2	-0.6	LOWER 95%	13.959	13.100	-1.881

REP #	9 DATSAS	8 DATSAS	8-9 DIFFER		9 DATSAS	8 DATSAS	8-9 DIFFER
1	13.9	13.3	-0.6	MEAN	15.200	13.320	-1.880
2	15.5	14.9	-0.6	STAND. DEV	1.691	0.863	1.670
3	12.8	12.4	-0.4	t .025,4	2.776	2.776	2.776
4	17.6	13.3	-4.3	UPPER 95%	17.300	14.392	0.194
5	16.2	12.7	-3.5	LOWER 95%	13.100	12.248	-3.954

SRUS WAITING

REP #	10 DATSAS	9 DATSAS	9-10 DIFFER		10 DATSAS	9 DATSAS	9-10 DIFFER
1	16.3	22.3	6.0	MEAN	15.480	19.680	4.200
2	13.2	17.1	3.9	STAND. DEV	2.168	3.548	2.186
3	19.0	25.3	6.3	t .025,4	2.776	2.776	2.776
4	15.7	15.9	0.2	UPPER 95%	18.172	24.084	6.914
5	13.2	17.8	4.6	LOWER 95%	12.788	15.276	1.486

REP #	9 DATSAS	8 DATSAS	8-9 DIFFER		9 DATSAS	8 DATSAS	8-9 DIFFER
1	22.3	37.5	15.2	MEAN	19.680	40.480	20.800
2	17.1	28.5	11.4	STAND. DEV	3.548	9.828	7.519
3	25.3	58.5	33.2	t .025,4	2.776	2.776	2.776
4	15.9	39.7	23.8	UPPER 95%	24.084	52.681	30.134
5	17.8	38.2	20.4	LOWER 95%	15.276	28.279	11.466

Appendix E: Changing the Number of Workers Data

USING: 8 DATSAS

DAYS IN DEPOT

REP #	50 WORKRS	45 WORKRS	50-45 DIFFER		50 WORKRS	45 WORKRS	50-45 DIFFER
1	4.427	4.594	-0.167	MEAN	4.767	4.928	-0.161
2	4.105	5.294	-1.189	STAND. DEV	0.553	0.518	0.546
3	5.753	5.758	-0.005	t .025,4	2.776	2.776	2.776
4	4.799	4.625	0.174	UPPER 95%	5.453	5.571	0.516
5	4.749	4.367	0.382	LOWER 95%	4.080	4.285	-0.838

REP #	45 WORKRS	40 WORKRS	45-40 DIFFER		45 WORKRS	40 WORKRS	45-40 DIFFER
1	4.594	5.020	-0.426	MEAN	4.928	9.747	-4.820
2	5.294	6.892	-1.598	STAND. DEV	0.518	3.422	3.611
3	5.758	9.880	-4.122	t .025,4	2.776	2.776	2.776
4	4.625	13.104	-8.479	UPPER 95%	5.571	13.995	-0.336
5	4.367	13.840	-9.473	LOWER 95%	4.285	5.499	-9.303

IDLE DATSAS

REP #	50 WORKRS	45 WORKRS	50-45 DIFFER		50 WORKRS	45 WORKRS	50-45 DIFFER
1	0.9	1.2	-0.3	MEAN	0.860	0.760	0.100
2	1.5	1.1	0.4	STAND. DEV	0.372	0.388	0.245
3	0.4	0.3	0.1	t .025,4	2.776	2.776	2.776
4	0.9	0.9	0	UPPER 95%	1.322	1.241	0.404
5	0.6	0.3	0.3	LOWER 95%	0.398	0.279	-0.204

REP #	45 WORKRS	40 WORKRS	45-40 DIFFER		45 WORKRS	40 WORKRS	45-40 DIFFER
1	1.2	1.2	0	MEAN	0.760	0.760	0.000
2	1.1	0.7	0.4	STAND. DEV	0.388	0.224	0.316
3	0.3	0.7	-0.4	t .025,4	2.776	2.776	2.776
4	0.9	0.6	0.3	UPPER 95%	1.241	1.039	0.393
5	0.3	0.6	-0.3	LOWER 95%	0.279	0.481	-0.393

IDLE WORKERS

REP #	50 WORKRS	45 WORKRS	50-45 DIFFER		50 WORKRS	45 WORKRS	50-45 DIFFER
1	13.3	9.6	3.7	MEAN	13.320	8.600	4.720
2	14.9	7.4	7.5	STAND. DEV	0.863	0.876	1.420
3	12.4	8.0	4.4	t .025,4	2.776	2.776	2.776
4	13.3	9.6	3.7	UPPER 95%	14.392	9.688	6.483
5	12.7	8.4	4.3	LOWER 95%	12.248	7.512	2.957

REP #	45 WORKRS	40 WORKRS	45-40 DIFFER		45 WORKRS	40 WORKRS	45-40 DIFFER
1	9.6	4.0	5.6	MEAN	8.600	3.360	5.240
2	7.4	2.6	4.8	STAND. DEV	0.876	0.484	0.575
3	8.0	3.1	4.9	t .025,4	2.776	2.776	2.776
4	9.6	3.4	6.2	UPPER 95%	9.688	3.961	5.954
5	8.4	3.7	4.7	LOWER 95%	7.512	2.759	4.526

SRUS WAITING

REP #	50 WORKRS	45 WORKRS	50-45 DIFFER		50 WORKRS	45 WORKRS	50-45 DIFFER
1	37.5	41.9	-4.4	MEAN	40.480	43.340	-2.860
2	28.5	44.9	-16.4	STAND. DEV	9.828	9.004	7.536
3	58.5	59.3	-0.8	t .025,4	2.776	2.776	2.776
4	39.7	38.2	1.5	UPPER 95%	52.681	54.518	6.496
5	38.2	32.4	5.8	LOWER 95%	28.279	32.162	-12.216

REP #	45 WORKRS	40 WORKRS	45-40 DIFFER		45 WORKRS	40 WORKRS	45-40 DIFFER
1	41.9	49.1	-7.2	MEAN	43.340	122.200	-78.860
2	44.9	71.9	-27.0	STAND. DEV	9.004	54.094	57.677
3	59.3	130.4	-71.1	t .025,4	2.776	2.776	2.776
4	38.2	174.6	-136.4	UPPER 95%	54.518	189.355	-7.256
5	32.4	185.0	-152.6	LOWER 95%	32.162	55.045	-150.464

Appendix F: Changing the Flying Time Data

USING: 8 DATSAS 50 WORKERS

DAYS IN DEPOT

REP #	NORM FLY	+10% FLY	DIFFER	---------- 8 DATSAS	NORM FLY	+10% FLY	DIFFER
1	4.211	5.854	1.643	MEAN	4.802	11.536	6.734
2	4.064	7.791	3.727	STAND. DEV	0.810	4.800	4.764
3	6.156	11.779	5.623	t .025,4	2.776	2.776	2.776
4	5.314	12.477	7.163	UPPER 95%	5.807	17.495	12.649
5	4.264	19.779	15.515	LOWER 95%	3.796	5.577	0.820

REP #	NORM FLY	-10% FLY	DIFFER	---------- 8 DATSAS	NORM FLY	-10% FLY	DIFFER
1	4.211	3.294	-0.917	MEAN	4.802	3.278	-1.524
2	4.064	2.939	-1.125	STAND. DEV	0.810	0.191	0.670
3	6.156	3.530	-2.626	t .025,4	2.776	2.776	2.776
4	5.314	3.338	-1.976	UPPER 95%	5.807	3.515	-0.692
5	4.264	3.288	-0.976	LOWER 95%	3.796	3.041	-2.356

IDLE DATSAS

REP #	NORM FLY	+10% FLY	DIFFER	---------- 8 DATSAS	NORM FLY	+10% FLY	DIFFER
1	1.3	0.4	-0.9	MEAN	0.700	0.180	-0.520
2	1.3	0.2	-1.1	STAND. DEV	0.502	0.117	0.412
3	0.1	0.1	0.0	t .025,4	2.776	2.776	2.776
4	0.4	0.1	-0.3	UPPER 95%	1.323	0.325	-0.009
5	0.4	0.1	-0.3	LOWER 95%	0.077	0.035	-1.031

REP #	NORM FLY	-10% FLY	DIFFER	---------- 8 DATSAS	NORM FLY	-10% FLY	DIFFER
1	1.3	2.2	0.9	MEAN	0.700	2.280	1.580
2	1.3	3.0	1.7	STAND. DEV	0.502	0.479	0.397
3	0.1	1.5	1.4	t .025,4	2.776	2.776	2.776
4	0.4	2.4	2.0	UPPER 95%	1.323	2.875	2.073
5	0.4	2.3	1.9	LOWER 95%	0.077	1.685	1.087

IDLE WORKERS

REP #	NORM FLY	+10% FLY	DIFFER	8 DATSAS	NORM FLY	+10% FLY	DIFFER
1	13.1	9.9	-3.2	MEAN	12.640	10.840	-1.800
2	14.5	8.8	-5.7	STAND. DEV	1.264	1.291	2.382
3	10.9	11.9	1.0	t .025,4	2.776	2.776	2.776
4	11.6	11.4	-0.2	UPPER 95%	14.210	12.443	1.158
5	13.1	12.2	-0.9	LOWER 95%	11.070	9.237	-4.758

REP #	NORM FLY	-10% FLY	DIFFER	8 DATSAS	NORM FLY	-10% FLY	DIFFER
1	13.1	18.6	5.5	MEAN	12.640	19.080	6.440
2	14.5	21.4	6.9	STAND. DEV	1.264	1.883	1.073
3	10.9	15.8	4.9	t .025,4	2.776	2.776	2.776
4	11.6	19.4	7.8	UPPER 95%	14.210	21.418	7.772
5	13.1	20.2	7.1	LOWER 95%	11.070	16.742	5.108

SRUS WAITING

REP #	NORM FLY	+10% FLY	DIFFER	8 DATSAS	NORM FLY	+10% FLY	DIFFER
1	33.7	68.0	34.3	MEAN	40.140	166.260	126.120
2	25.9	95.0	69.1	STAND. DEV	14.337	83.157	83.050
3	65.1	178.2	113.1	t .025,4	2.776	2.776	2.776
4	46.7	184.7	138.0	UPPER 95%	57.939	269.497	229.224
5	29.3	305.4	276.1	LOWER 95%	22.341	63.023	23.016

REP #	NORM FLY	-10% FLY	DIFFER	8 DATSAS	NORM FLY	-10% FLY	DIFFER
1	33.7	17.1	-16.6	MEAN	40.140	16.340	-23.800
2	25.9	12.4	-13.5	STAND. DEV	14.337	2.310	12.452
3	65.1	19.5	-45.6	t .025,4	2.776	2.776	2.776
4	46.7	16.9	-29.8	UPPER 95%	57.939	19.208	-8.341
5	29.3	15.8	-13.5	LOWER 95%	22.341	13.472	-39.259

USING: 9 DATSAS 50 WORKERS

DAYS IN DEPOT

REP #	NORM FLY	+10% FLY	DIFFER	9 DATSAS	NORM FLY	+10% FLY	DIFFER
1	3.472	4.133	0.661	MEAN	3.403	4.115	0.712
2	3.392	3.359	-0.033	STAND. DEV	0.233	0.515	0.413
3	3.784	4.977	1.193	t .025,4	2.776	2.776	2.776
4	3.072	4.031	0.959	UPPER 95%	3.692	4.754	1.226
5	3.293	4.075	0.782	LOWER 95%	3.113	3.476	0.199

REP #	NORM FLY	-10% FLY	DIFFER	9 DATSAS	NORM FLY	-10% FLY	DIFFER
1	3.472	3.085	-0.387	MEAN	3.403	3.118	-0.284
2	3.392	2.814	-0.578	STAND. DEV	0.233	0.184	0.330
3	3.784	3.206	-0.578	t .025,4	2.776	2.776	2.776
4	3.072	3.380	0.308	UPPER 95%	3.692	3.347	0.125
5	3.293	3.106	-0.187	LOWER 95%	3.113	2.889	-0.694

IDLE DATSAS

REP #	NORM FLY	+10% FLY	DIFFER	9 DATSAS	NORM FLY	+10% FLY	DIFFER
1	2.2	1.5	-0.7	MEAN	2.420	1.420	-1.000
2	2.7	2.5	-0.2	STAND. DEV	0.685	0.668	0.597
3	1.3	0.4	-0.9	t .025,4	2.776	2.776	2.776
4	3.4	1.4	-2	UPPER 95%	3.271	2.249	-0.259
5	2.5	1.3	-1.2	LOWER 95%	1.569	0.591	-1.741

REP #	NORM FLY	-10% FLY	DIFFER	9 DATSAS	NORM FLY	-10% FLY	DIFFER
1	2.2	3.5	1.3	MEAN	2.420	3.280	0.860
2	2.7	4.0	1.3	STAND. DEV	0.685	0.462	0.900
3	1.3	3.1	1.8	t .025,4	2.776	2.776	2.776
4	3.4	2.6	-0.8	UPPER 95%	3.271	3.854	1.978
5	2.5	3.2	0.7	LOWER 95%	1.569	2.706	-0.258

IDLE WORKERS

REP #	NORM FLY	+10% FLY	DIFFER	9 DATSAS	NORM FLY	+10% FLY	DIFFER
1	13.9	9.6	-4.3	MEAN	15.200	10.760	-4.440
2	15.5	14.4	-1.1	STAND. DEV	1.691	2.111	1.838
3	12.8	8.0	-4.8	t .025,4	2.776	2.776	2.776
4	17.6	11.0	-6.6	UPPER 95%	17.300	13.380	-2.158
5	16.2	10.8	-5.4	LOWER 95%	13.100	8.140	-6.722

REP #	NORM FLY	-10% FLY	DIFFER	9 DATSAS	NORM FLY	-10% FLY	DIFFER
1	13.9	18.8	4.9	MEAN	15.200	19.360	4.160
2	15.5	22.4	6.9	STAND. DEV	1.691	1.717	1.955
3	12.8	17.3	4.5	t .025,4	2.776	2.776	2.776
4	17.6	18.5	0.9	UPPER 95%	17.300	21.491	6.587
5	16.2	19.8	3.6	LOWER 95%	13.100	17.229	1.733

SRUS WAITING

REP #	NORM FLY	+10% FLY	DIFFER	9 DATSAS	NORM FLY	+10% FLY	DIFFER
1	22.3	36.0	13.7	MEAN	19.680	33.260	13.580
2	17.1	20.3	3.2	STAND. DEV	3.548	9.107	6.377
3	25.3	48.3	23.0	t .025,4	2.776	2.776	2.776
4	15.9	31.7	15.8	UPPER 95%	24.084	44.567	21.497
5	17.8	30.0	12.2	LOWER 95%	15.276	21.953	5.663

REP #	NORM FLY	-10% FLY	DIFFER	9 DATSAS	NORM FLY	-10% FLY	DIFFER
1	22.3	14.2	-8.1	MEAN	19.680	14.100	-5.580
2	17.1	10.8	-6.3	STAND. DEV	3.548	2.280	3.872
3	25.3	15.5	-9.8	t .025,4	2.776	2.776	2.776
4	15.9	17.4	1.5	UPPER 95%	24.084	16.931	-0.773
5	17.8	12.6	-5.2	LOWER 95%	15.276	11.269	-10.387

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Abstract

This research investigates the repair process for B1-B avionic Shop Replaceable Units (SRUs) at the depot level of maintenance. A Depot Automated Test Station for Avionics (DATSA) is used to test these SRUs for faults. A computer model provides the environment for the simulation and comparison of different amounts of DATSAs at the depot at Robbins AFB, Georgia.

SIMPLE 1 is the simulation language used by the model. It was chosen primarily because it can be used on any IBM or IBM compatible personal computer, and it does not require a simulation expert to run. The model's user-friendly input screens allow for changes to be made for future simulations as more data becomes available on the SRU repair process.

The simulations used a SRU arrival rate based on an aggregate Mean Time Between Demand for the SRUs. Simulations were conducted using various quantities of DATSAS. The differences between key variables in the different systems were compared and confidence intervals were computed. Synchronized random number streams were used as a variance reduction technique to determine compact confidence intervals. Sensitivity analysis was also accomplished by varying the quantities of workers available and the average daily flying time of the B1-B.

The results indicated a minimum of eight test stations would be able to accomodate the anticipated SRU load at the depot. However, the time the average SRU was delayed in the depot also increased as the number of DATSAs was decreased. With only eight DATSAs in operation, the cost of the added delay might exceed the cost of another DATSA. Also, as the flying time was increased, an infinite queue of faulty SRUs began to accumulate with only eight DATSAs in operation. Nine DATSAs were easily able to accomodate a 10 percent increase in average daily flying time.

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